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ANALYSIS OF *VARROA DESTRUCTOR* INFESTATION OF SOUTHERN AFRICAN HONEYBEE POPULATIONS

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ABSTRACT

The discovery of the honeybee-specific ectoparasitic mite *Varroa destructor* in South Africa in October 1997 raised the spectre of massive honeybee colony losses as has occurred in most parts of the world where the varroa mite has been found. This was particularly concerning in Africa because of the importance of honeybees in the pollination of indigenous and commercial crops, and because of the numbers of small-scale beekeepers in Africa. The mite has now spread throughout South Africa and is found in almost all honeybee populations, both commercial and wild, and is also now present in most neighbouring countries. *Varroa* has not left a trail of destruction in South Africa as had been expected and no large scale collapse of the honeybee population occurred, despite the majority of beekeepers deciding not to protect their hives with chemical varroacides. Some colony losses did occur at the front of the varroa spread, and all colonies were found to be deleteriously affected by the mite which developed populations of 50 000 and more in some colonies. Infected colonies were also not as efficient as pollinators as uninfected colonies. Colonies exhibited all the same varroa effects witnessed in other parts of the world, with the exception that the majority of colonies did not die as a result of the infestation. The relative tolerance of African bees to the varroa mite has been confirmed by the long-term monitoring of both wild honeybee populations and commercial stock, and by population dynamic studies of the mites. In both wild and managed honeybee populations varroa appears to have been reduced to the status of an incidental pest. The development of mite tolerance took 3-5 years in the Cape honeybee (*Apis mellifera capensis*) and 6-7 years in the Savanna honeybee (*Apis mellifera scutellata*). The rapid development of mite tolerance in the Cape bee is thought to be due to the well developed removal of varroa-infested brood and the short post-capping period of worker brood. Together these resulted in a very rapid increase in infertile mites in the colony, the collapse of the mite population, and varroa tolerance. Tolerance does not develop as rapidly in Savanna honeybees as the post-capping period in these bees is similar to that of European bees and does not result in as many infertile mites. Nonetheless, varroa tolerance in Savanna bees develops more rapidly than would be the case in European bees because of more effective hygienic removal of varroa-infested brood. In both Cape and Savanna bees, the absence of varroacide applications and a “live-and-let-die” approach to the wild and commercial honeybee populations was crucial to the developed of population-wide varroa tolerance, in contrast to the selective breeding and pesticide treadmill practised in most parts of the world in an effort to get rid of the varroa mite. *Varroa destructor* is concluded not to be a serious threat to honeybees and beekeeping in Africa, and efforts should be made to prevent the use of pesticides and techniques that could hinder the development of natural mite tolerance in Africa.

DECLARATION

I declare that "**Analysis of *Varroa destructor* infestation of southern African honeybee populations**" is my own work unless otherwise indicated.

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Mike Allsopp June 9th 2006

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PUBLICATIONS AND CONFERENCE PROCEEDINGS

A list of publications and conference proceedings emanating from this research, or closely allied to this research:

Refereed articles

1. Allsopp M H, Govan V & Davison S 1997. Bee Health Report: Varroa in South Africa. **Bee World**, 78, 171-174.
2. Govan V A, Leat N, Allsopp M H & Davison S 2000. The complete nucleotide sequence of a honeybee virus (Acute bee paralysis virus) that belongs to the novel group of insect-infecting RNA viruses. **Virology**, 277, 457-463.
3. Benjiddou M, Leat N, Allsopp M H & Davison S 2000. Detection of acute bee-paralysis virus and black queen-cell virus in honey bees by Reverse-Transcriptase-PCR. **Applied & Environmental Microbiology** 67(5), 2384-2387.
4. Allsopp M H 2001. Varroa in Africa – A serious threat. XXXVII **Proceedings of the 37th International Apicultural Congress**, Durban, South Africa, Apimondia, 212-219.
5. Allsopp M H 2002. Varroa in South Africa - the Early Years. In **Proceedings of the 2nd International Conference on Africanized Honey Bees and Bee Mites,** Ed. Eric H. Erickson Jr., Robert E. Page Jr. & Anita A. Hanna. A.I. Root Company, Medina, Ohio, pp. 117 –126.
6. Lach, L, Picker, M. D., Allsopp, M., Colville, J., & Griffiths, C. L. 2002 Alien invertebrate animals in South Africa. In: **Biological Invasions: Economic and environmental costs of alien plant, animal and microbe species**. Pimental, D (ed.), CRC Press, London, pp. 267 – 282.
7. Benjeddou, M., Leat, N., Allsopp, M. & Davison, S. 2002. Development of Infectious Transcripts and Genome Manipulation of the Black Queen-Cell Virus of Honeybees. **J. Gen. Virol,** 83, 3139-3146.
8. Allsopp M. H. 2004. Cape honeybee (*Apis mellifera capensis* Eshscholtz) and Varroa mite (*Varroa destructor* Anderson & Trueman) threats to honeybees and beekeeping in Africa. **International Journal of Tropical Insect Science**, 24, 87-94.
9. Kassimatis E. J., Allsopp M. H. & Dippenaar-Schoeman A. S. 2004 A review of the genus *Ellingsenius* (J.C. Chamberlin) (Pseudoscorpiones: Cheliferidae), pseudoscorpions associated with honeybee colonies in South Africa, and their significance for the control of *Varroa* mites (Acari: Mesostigmata; Varroadae). **Cimbebasia**, (in press).

Non-refereed articles

1. Allsopp M H 1997. Varroa in the Western Cape. **South African Bee Journal**, 69, 33-35.
2. Allsopp M H 1997. Varroa mite discovered in South Africa. **Agricultural News**, 18, September 8.

3. Allsopp M H 1997. The honeybee parasitic mite *Varroa jacobsoni* in South Africa. **South African Bee Journal**, 69, 73-82.
4. Allsopp M H 1997. The Capensis Problem and Varroa - a marriage made in hell? **South African Bee Journal**, 69, 82-85.
5. Allsopp M H 1997. Tracheal mites in South Africa - time for a better look? **South African Bee Journal**, 69, 93-95.
6. Allsopp M H 1998. Survey for *Varroa jacobsoni* in South Africa. **South African Bee Journal**, 70, 145-154.
7. Anderson A J & Allsopp M H 1998. A preliminary evaluation of the organic control of *Varroa jacobsoni* in Cape honeybees. **Natal Bee-Mail,** summer edition, pps. 18-25.
8. Allsopp M H 1999. The Problem of the Varroa mite as a pest of honeybees as pollinators. **Yearbook of the SA Litchi Growers' Association**, 10, 26-27.
9. Allsopp M H 1999. Varroa mite threatens African honeybees. **Plant Protection News**, 55, 6-7.
10. Allsopp M H 1999. The Varroa mite and the Deciduous Fruit Industry. **Deciduous Fruit Grower**, 48 (9), 24-26.
11. Allsopp M H (1999) Might varroa cure the Capenis Problem? **South African Bee Journal**, 71(3), 80-81.
12. Anderson A J & Allsopp M H 1999. A preliminary evaluation of the organic control of *Varroa jacobsoni* in Cape honeybees. **South African Bee Journal**, 71, 12-20.
13. Allsopp M H, Swart D, van den Heever R & Kryger P 1999. The latest on varroa in South Africa. **South African Bee Journal**, 71, 23-25.
14. Davison S, Govan V, Leat N & Allsopp M 1999. Bee Diseases in South Africa I: EFB, AFB, Chalkbrood and bee viruses. **South African Bee Journal**, 71, 84-87.
15. Allsopp M H 2000. A varroa update. **South African Bee Journal**, 72, 25-27.
16. Allsopp M H 2001 Varroa mites threaten honeybees, beekeepers and commercial pollination in South Africa. In **Proceedings of the Cape Pomological Association Technical Symposium**, Stellenbosch, 5th June.
17. Allsopp MH 2001. Varroacides: Use & Abuse. **South African Bee Journal**, 73, 172-173.
18. Allsopp M H, E J Kassimatis, D J Swart & A S Dippenaar-Schoeman. 2003 No evidence that pseudoscorpions are controlling varroa mites in South African honeybee colonies. **South African Bee Journal,** 75, 61-66.

Congress Proceedings

1. Allsopp M H 1998. Varroa, a new threat to beekeeping in South Africa. **Varroa Forum**, Elsenburg, February 10.
2. Govan, V A, Leat N, Allsopp M H & Davison S 1998. Sequence analysis of honeybee viruses. **5th Symposium on Positive Stranded RNA Viruses**. Miami, May 1998.
3. Allsopp M H 1998. Parasitic Bee Mites: Are we in trouble? **Cape Pomological Association Technical Symposium**, Cape Town, 2-3 June.

4. Govan V, Leat N, Allsopp M & Davison S. 1998. Comparison of three honeybee virus genomes**. 10th Congress of the South African Society of Microbiology**, Durban, 5-8 July.
5. Allsopp M H 1998. Status report: varroa in South Africa**. Northern Transvaal Beekeepers Association 60th Jubilee Symposium**, Pretoria, 30 Sept – 2 Oct.
6. Allsopp M H 1998. The problem of varroa mites as a pest of honeybees as pollinators**. SA Litchi Growers Symposium**, Nelspruit, 22 Oct.
7. Govan, V A, Leat N, Allsopp M H & Davison S 1998. Sequence comparison of honeybee viruses. **Virology Conference of Southern Africa**. Cape Town, October.
8. Govan V, Allsopp M H & Davison S 1999. Nucleotide sequence of APV shows that it belongs to a picorna-like virus family**. 11th International Virology Congress**, Sydney, 9-13th August.
9. Allsopp M H 1999. Are selective breeding and stock maintenance possible in South Africa? **36th Apimondia Congress**, Vancouver, 11-18th September.
10. Benjeddou M, Leat N, Allsopp M H & Davison S 2000. Development of PCR primers for the detection of viruses in honeybees. **South African Society for Microbiology BIOY2K Millennium Meeting**. Grahamstown, January.
11. Govan V A, Allsopp M H & Davison S 2000. The novel genome organization of Acute Bee Paralysis Virus suggests this virus belongs to a recently discovered virus family. **South African Society for Microbiology BIOY2K Millennium Meeting**. Grahamstown, January.
12. Allsopp M H 2000. Varroa in South Africa- the Early Years. **Second International Conference on Bee Mites and Africanized Honeybees.** Tucson, 10-15th April.
13. Allsopp M H 2001. Varroa mites threaten honeybees, beekeepers and commercial pollination in South Africa. **Cape Pomological Association Technical Symposium**, Stellenbosch, 5th June
14. Allsopp M H 2001. Reproduction of the varroa mite *Varroa destructor* in Cape honeybees *Apis mellifera capensis*. **13th Congress of the Entomological Association of Southern Africa**, Pietermaritzburg, 2-5th July.
15. Allsopp M H 2001. Varroa in Africa – A serious threat. XXXVII **Apimondia Congress**, 28th October – 1st November, Durban.
16. M. Benjeddou, N. Leat, M. Allsopp and S. Davison.2002. Development of Infectious Transcripts and Genome Manipulation of the Black Queen-Cell Virus of Honeybees by Long Reverse Transcription-PCR. **12th Congress of the South African Society for Microbiology**, Bloemfontein, April 2002
17. Allsopp M H 2002 Cape honeybees and varroa mite threat to honeybees and beekeeping in Africa. **African Pollinators Initiative (API) Workshop**, Nairobi, 18th – 22nd February.
18. Allsopp M H 2002. The threat of varroa to beekeeping in Africa. **Bees without frontiers: 6th European Bee Conference**, Cardiff, 1-5th July.
19. Allsopp M H 2002 Alternative products for the control of the varroa mite. **SABIE BeeCon 2002**, 19 July.
20. Kassimatis E, Allsopp M H, Swart D & Dippenaar-Schoeman A. 2002. Can Pseudoscorpions play a role in the control of varroa mites in honeybee colonies in South Africa? **7th African Arachnological Colloquim**. Durban, July 2002.

21. Johns J, Allsopp M H & Davison S 2003. Varroa mite transmission of honeybee viruses results in pupal mortality. **14th Entomological Congress of South Africa**, Pretoria, 6-9 July.
22. Allsopp M H 2003 Varroa mite (*Varroa destructor*) tolerance in Cape honeybees (*Apis mellifera capensis*). **14th Entomological Congress of South Africa**, Pretoria, 6-9 July.

CHAPTER ONE

VARROA MITES AND SOUTH AFRICAN HONEYBEES

The most serious pest of honeybees in the 20th century has undoubtedly been the ectoparasitic mite, *Varroa destructor* (formerly *Varroa jacobsoni*). Relatively harmless on its natural host, the Eastern honeybee *Apis cerana*, the varroa mite has recently crossed onto the Western honeybee *Apis mellifera* and spread from its Asian origins throughout most of the world. On the commercially important *Apis mellifera* the varroa mite is no longer a relatively benign pest, and the result in most cases is the death of the honeybee colony. In regions of the world where the varroa mite is well established, such as Europe and the USA, wild honeybee populations have all but disappeared as a result of varroa mortality, and commercial beekeeping is only possible with the liberal use of acaricides.

The detection in 1997 of the mite in South Africa, historically free of serious honeybee pests and diseases, constitutes the most serious threat in history to the beekeeping industry, to agriculture dependent on honeybee pollination, and to the multitude of indigenous plant species depending on these honeybees for survival, in this country.

VARROA DESTRUCTOR

Description

The varroa mite, *Varroa jacobsoni* Oudemans, that has been reported to have caused devastation to honeybee populations almost throughout the world for the past thirty years is no longer considered to be a single species, but rather a species complex (Anderson 2000), and the population responsible for the damage has been misidentified. *Varroa jacobsoni* was first identified by A.C. Oudemans in the Netherlands in 1904 from specimens collected in Java by E. Jacobson. The opportunistic leap by the mite onto *Apis mellifera* and subsequent worldwide range expansion led to this species being labelled as the culprit. Comprehensive mitochondrial DNA testing has, however, demonstrated that this single species is a species complex of at least two and possibly as many as five cryptic species (Anderson & Trueman 2000; Anderson 2002) with as many as twenty mite genotypes being present (Anderson 2002). Furthermore, each mitotype has differing virulence towards their hosts (Anderson & Fuchs 1998), and only two types are able to reproduce on *Apis mellifera.* Of these only one, the Korean-Russian type, is responsible for the damage to honeybee colonies witnessed in Europe and the USA (Anderson 2000) and this species has been re-named *Varroa destructor* Anderson and Trueman (2000). It is this mitotype that has been found in South Africa (Anderson 2000).

Varroa destructor is reddish brown in colour, flat and oval in shape, 1.1 mm long and 1.5 mm wide (Figure 1.1). It is found between the abdominal segments or body regions of adult bees, particularly adjacent to the wax glands, or in the honeybee brood. When present in extremely high numbers in a honeybee colony, mites are readily seen on the thorax of honeybees (Figure 1.2). *Varroa destructor* is very similar in appearance to the apparently harmless common bee louse *Braula coeca*, which is found in most beehives in South Africa, but can be readily identified by body shape and the eight legs of the mite rather than the six legs of the louse.

Figure 1.1: The varroa mite *Varroa destructor* Anderson and Trueman (2000).

Spread

Varroa destructor (identified as *V. jacobsoni*) was identified for the first time on *A. mellifera* in 1958 (Mikawa 1986) and the uncontrolled movement of bees by humans has lead to the subsequent spread of the parasite to Europe (1967), North Africa (1975), South America (1971) and to the USA in 1987 (De Jong *et al* 1984; Needham 1988; Matheson 1995). The spread of the varroa mite across the globe has increased in recent years, with countries such as Costa Rica, South Africa, Panama and New Zealand all having detected the mite in the last five years (Allsopp *et al* 1997; Van Heen *et al* 1998; Calderon *et al* 2000; Harman 2000). Of the major regions in the world, only Australia and central Africa are at present free of the varroa mite.

Figure 1.2: Varroa mites are typically found between honeybee abdominal segments, but also on the thorax at high densities.

Until recently, varroa mites could be found in Africa only in those countries bordering on the Mediterranean where it has been well established for twenty years (Matheson 1993), disregarding unconfirmed reports from Senegal and Niger (Matheson 1993, 1996). Its recent surprise appearance in South Africa is sure to have followed the *modus operandi* of its earlier spread; the commercial transport of bees and queens, the migratory activity of beekeepers, and swarms that can be carried in aircraft and ships (Shimanuki *et al* 1992). To this list can be added the practice of international aid agencies introducing foreign honeybees to countries and continents for development beekeeping purposes (Matheson 1995). As it can take years after the initial infestation until mite numbers are sufficient to be noticed, the mite is likely to have been present in South Africa for a number of years before 1997.

The mite spreads between honeybee colonies through the drifting of foraging bees and drones, and the robbing of hives by foraging bees, and by migrating honeybee swarms. The use of honeybee colonies in commercial pollination, which brings into close proximity colonies that were widely dispersed, accelerates the spread. The long-distance migration of honeybee swarms by beekeepers, for commercial pollination and to exploit honey-flows, results in the rapid wider dispersal of the mite.

Life Cycle

Varroa mites cause limited damage on their natural host *Apis cerana* (Koeniger 1985) where the parasite-host relationship appears to have reached equilibrium due to the development of defence mechanisms in the host (Peng *et al* 1987). The entire lifecycle of varroa mites occurs in the bee-hive and all stages are obligate ectoparasites feeding on haemolymph (Figure 1.3). Fertilized female mites invade a cell containing a bee larva, attracted to the cell by volatiles released by the bee larvae prior to

cell capping (Le Conte *et al* 1989), and prefer drone brood cells to worker cells (Fuchs 1990). The mite conceals itself in the royal jelly until the cell is capped (Ifantidis 1988) and once the cell is capped, feeds on the haemolymph of the larva and lay eggs in the cell (Boot *et al* 1992). The first egg laid typically develops into a male, and all subsequent eggs into female mites (Shimanuki *et al* 1992). Normal reproduction consists of the production of one male and two-four females which are fertilized by their brother before the emergence of the adult bee (Ifantidis 1990). The male offspring then dies, and the mother mite and her mated daughters leave the cell when the young bee emerges. Adult mites live off the blood of adult bees, have a lifespan of 2-3 months, and a female may produce two, or at most three, broods (Fries *et al* 1994).

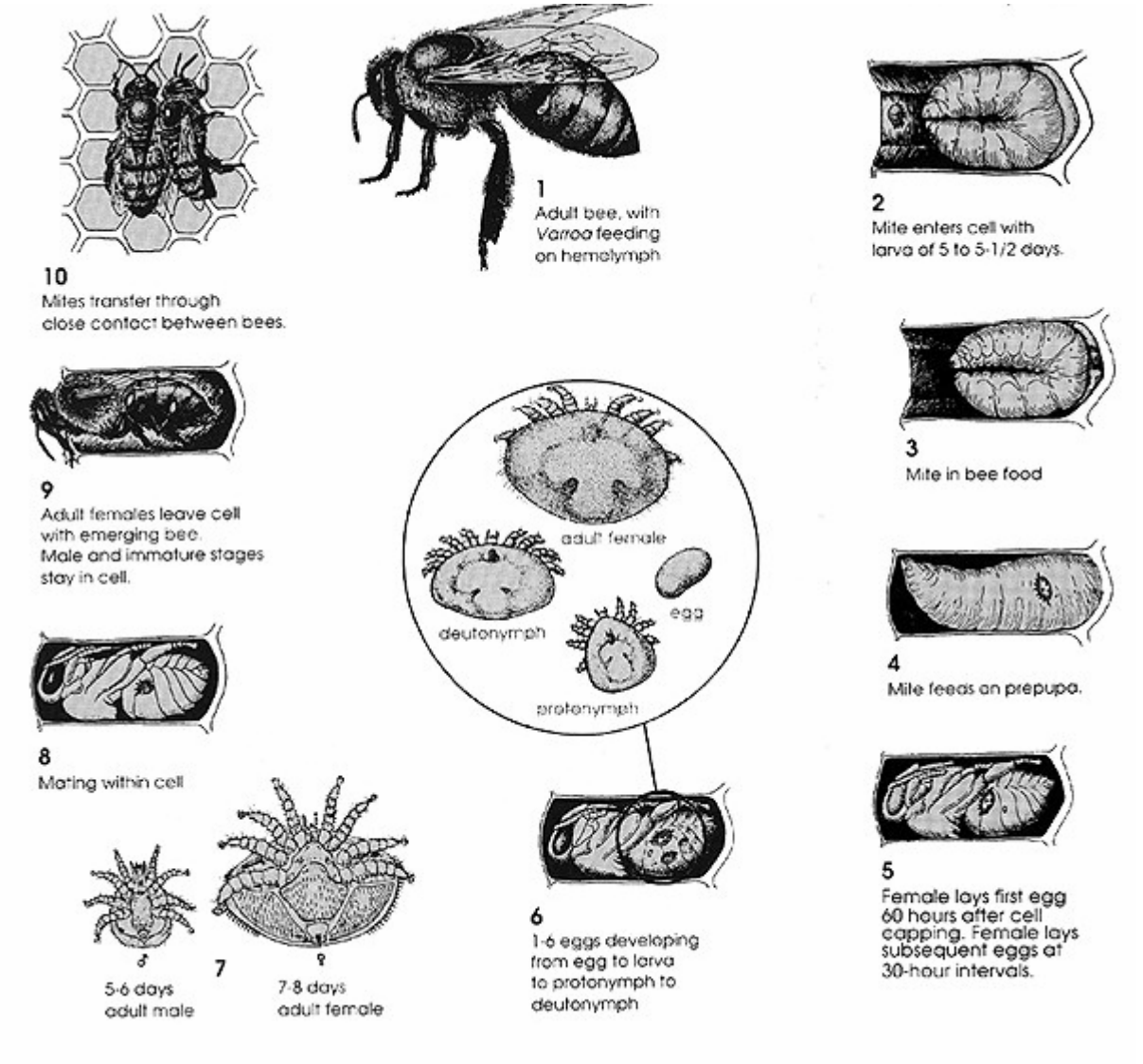


Figure 1.3: Life cycle of *Varroa destructor* (adapted from Henderson *et al* 1986).

Impact

In Asian honeybees mite numbers are restricted by the amount of drone brood present in the colonies, but in *Apis mellifera* mites are able to reproduce on all available brood, leading to an explosion in the parasite population (Peng *et al* 1987). Large numbers of mites cause brood death while lesser infestations result in abnormalities in the brood, typically compacted size and vestigial wings. The adult bee is the intermediate host on which adult varroa survive, the mites sucking blood which weakens the bees and reduces life expectancy. The combination of adult mortality, brood mortality and brood abnormalities weaken the colony and eventually cause its death (Fries *et al* 1994).

There is considerable variability in the number of mites necessary to cause colony collapse (Martin 1997a; Martin *et al* 1998), and it has been found that in addition to the physical damage caused by the feeding of the mites, honeybee colony collapse is caused by secondary pathogens vectored or activated by the mites. In particular there is a close link between varroa and virus activation in honeybee colonies, with a host of viruses having been implicated (Ball & Allen 1988; Ball 1997; Pohl & Ritter 1997; Sammatoro 1997; Martin 1997a; Otteni & Ritter 1998; Martin *et al* 1998; Bowen-Walker *et al* 1998). Colonies of honeybees typically sustain high levels of mites for a variable period of time, and then suddenly collapse and die, with both viruses and bacterial pathogens involved in these later stages. Prior to this colony collapse, colonies sustaining high varroa levels also exhibit reduced honey production (Ericksen *et al* 1998) as well as reduced numbers of drones (Rinderer *et al* 1999) that can limit the mating success of the honeybee population.

In Europe and the USA many hundreds of thousands of commercial honeybee colonies have died as a result of varroatosis, and beekeeping is considered to be no longer possible without some anti-varroa treatment (Bailey & Ball 1991). Varroa infestation is generally considered lethal for European races of *Apis mellifera* (Ruttner 1983). Colony losses due to the mite normally take some 2-7 years after the first detection of the parasite (De Jong *et al* 1982; Martin 1997a), but once established *Varroa* has been responsible for 60% colony losses of commercial honeybee colonies and 95% losses of feral honeybee colonies (Kraus & Page 1995b; Kraus & Hunt 1995; Finley *et al* 1996; Loper 1997; Page 1998; Hunt 1998). Colonies need not necessarily exhibit extreme effects of mite infestation to suffer damage, or to lose effectiveness as pollinators. Kralj and Fuchs (2002) showed that mite infestation influences flight behaviour and can both decrease flight duration and increase the loss of workers during foraging.

Once the mite is established in a region, beekeeping is only possible with the chemical treatment of colonies to control the varroa. Wild colonies, beyond the reach of chemical treatment, are obviously at greatest risk, with severe implications for the indigenous and cultivated flora dependent on these honeybees for pollination. The conservation value of honeybees is enormous, though immeasurable (Free 1993). Research done by Kraus and Page (1995b) on feral colonies in an area near Sacramento, California, indicate that *V. destructor* infestation led to a 75% loss of feral colonies within a year. The ecological implications of a similar impact in South Africa, with its massive wild honeybee

population, enormous floral diversity and considerable demand on subsistence agriculture, are staggering.

Treatment

There is no totally effective treatment for *Varroa*. A very large number of chemicals have been used to control varroa mite, both “hard” and “soft” chemicals. The “hard” chemicals include products such as Apistan (fluvalinate), Perizin (coumaphos), Bayvarol (flumethrin) and Apivar (amitraz), all of which effect dramatic mite control in the order of 97-100% (Krieger 1995, Haupt *et al* 1996, Fries 1997, Wilson *et al* 1998). “Softer” chemicals, such as thymol and formic acid, do not give the same degree of control (Imdorf *et al* 1996; Anderson & Allsopp 1999).

There are two general difficulties with the use of the “harder” varroacides. Firstly, the repeated use of the products results in the development of resistance in the varroa mites to the product. Mite resistance has been reported for almost all varroacides used (Watkins 1996, Trouiller 1998, Milani 1999, Elzen *et al* 1999; Spreafico *et al* 2001; Thompson *et al* 2002). Varroa populations have been shown to be highly resistant to fluvalinate in many parts of Europe (Loglio & Plebani 1992; Milani 1995; Lodesani *et al* 1995; Gufner & Wallner 1995; Moosbeckhofer 1996; Watkins 1996; Thomas 1997; Colin *et al* 1997; Trouiller 1998), Israel (Gerson *et al* 1991) and the USA (Moosbeckhofer 1996; Eischen 1998a; Elzen *et al* 1998). This has been shown by Cabras *et al* 1997 to be real resistance and not some problem with the active ingredient. In addition, varroa populations resistant to acinathrin (Milani 1995; Trouiller 1998), coumaphos (Lodesani 1996; Vedova *et al* 1997; Spreafico *et al* 2001), flumethrin (Thompson *et al* 2002) and amitraz (Trouiller 1998; Elzen *et al* 1998) have also been found. Furthermore, cross-resistance to all the pyrethroids used against varroa has been found in a number of varroa populations (Milani 1995; Watkins 1996; Fries 1997).

This development of resistance by varroa to directed miticides, possibly resulting from increased detoxification due to increased monooxygenase activity (Watkins 1996; Hillesheim *et al* 1996), is suggested to result from the following (Watkins 1996): treatment at too low a level; too frequent treatment; treatment when unnecessary; treatment for too long a period; and uncontrolled usage of unregistered chemicals. Whatever the causes, it is apparent that resistance to most varroacides has developed, and that it is necessary to have a number of products that can be used against varroa in a controlled, integrated and responsible manner. It is equally apparent that the economic threshold for the chemical treatment of a varroa population needs to be established (Delaplane & Hood 1999), and that treatment should be as infrequent as possible.

The second major problem with the directed varroacides is that the presence of residues from the varroacide in the honey and wax (Fries *et al* 1998, Bogdanov *et al* 1998, Wallner 1999) threatens the healthy and pure image of bee products, as well as contributing to further varroacide resistance development. The yearly treatment with an acaracide may effectively control the varroa population, but may have the disadvantage of contaminating bee products such as wax, honey, pollen and propolis.

None of the directed miticides amitraz, fluvalinate or coumaphos have been found in measurable amounts in honey (Thrasyvoulou & Pappas 1988; Bogdanov *et al* 1990; Lodesani *et al* 1992; Van Buren *et al* 1992; Brödsgaard *et al* 1998), but coumaphos, fluvalinate and bromopropylate have been found to accumulate in both wax and propolis (Thrasyvoulou & Pappas 1988; Hansen & Petersen 1988; Bogdanov *et al* 1990; Lodesani *et al* 1992; Van Buren *et al* 1992; Van Greef *et al* 1994; Bogdanov *et al* 1998). The concentration of the varroacides in the wax is most troubling as wax is continually recycled by beekeepers. Almost all wax offered for sale in Europe is contaminated by varroacides (Wallner 1997), and it has been found that a single treatment with any of the varroacides is sufficient for residues of the varroacide to be detected in the wax (Bogdanov *et al* 1998). The concentration of the varroacide increases in the wax as more chemical treatments are used (Bogdanov *et al* 1998), and the residues of the varroacide in the wax have been shown to effect varroa control in colonies where this wax is used (Fries *et al* 1998). This has obvious implications for the development of resistance to these varroacides.

The active ingredients (ai's) of the varroacides used fall into two categories: water soluble (hydrophilic) or fat-soluble (lipophilic). All hydrophilic compounds (for example, formic acid) endanger the purity of honey, but have no effect on the wax. In contrast, the fat-soluble varroacides (which include fluvalinate, flumethrin, bromopropylate, coumaphos and amitraz) all increase in the wax comb, and migrate from the wax to the stored honey (Wallner 1999). The greater the concentration of these products in the comb wax, the more of the product will appear in the honey. Furthermore, most of these products are extremely stable, and will continue to increase in concentration in the wax due to repeated pesticide applications. The recycling of wax has no effect on the residues (Wallner 1999) and the quality of the wax is permanently damaged by the residues. These fat-soluble varroacides, as effective as they are against the varroa mite, pose the "greatest risk to apiculture in terms of long-term residue accumulation" (Wallner 1999).

Within the fat-soluble group of varroacides there are some that are either volatile or unstable, such as thymol and amitraz. These varroacides rapidly decay into metabolites, and do not accumulate in beeswax, with only a trace being present as little as three weeks after use. Amitraz is unstable in honey, completely degrading to metabolites in 3-4 weeks, and amitraz residues are never detected in honey (Bogdanov 1988, Fernandez Muiso & Simal Lozano 1993). Amitraz is also unstable in beeswax, with beeswax actually accelerating degradation (Wallner 1999). At present there are large amounts of residues from all the commonly used varroacides in the beeswax of Europe, with the sole exception of amitraz (Wallner 1999).

The alternative chemical treatments have gained great currency in recent years, as they are perceived to be "softer", or to be of "natural" origin. Certainly, all these alternative varroa treatments are cheaper, but they are also all less effective (Imdorf *et al* 1996). The most commonly used alternative compound is formic acid, of which there are many formulations and devices for varroa treatment. Varroa control with formic acid is in the efficacy range of 26-77% (Feldlaufer *et al* 1997; Moosbeckhofer *et al* 1997;

Eischen 1998b; Calis *et al* 1998; Anderson & Allsopp 1999), is very variable and is temperature dependent. In addition, formic acid is not much liked by the bees, can kill brood (Fries 1989) or queens (Bolli *et al* 1993) and can cause colonies to abscond (Anderson & Allsopp 1999). Oxalic acid is another alternative that has been used for varroa control, and has probably achieved greatest success, with mite fall being in the order of 95% (Mutinelli *et al* 1997; Anderson & Allsopp 1999). Oxalic acid is, however, difficult and time consuming to use.

In addition to acids, at least fifty essential oils and plant extracts have been tested for their value in varroa control (Kraus *et al* 1994; Eischen & Wilson 1997; Calderone & Spivak 1997; Eischen & Wilson 1998; Sammatoro *et al* 1998). Most of these extracts cause the mites to release from the bees, but do not cause mite mortality, and are therefore of limited value. The most widely used extract is thymol, which has been incorporated in a number of varroa-control devices. Mite control using thymol ranges from 80-99% (Imdorf *et al* 1995; Krieger 1995; Higes *et al* 1997), but again the product is difficult to use and results are variable. Other alternative varroacides used include lactic acid, sulfur, ethereal oils and cupric salts (Garg & Sharma 1988; Hoppe *et al* 1989; Kraus *et al* 1994; Imdorf *et al* 1995; Imdorf *et al* 1996; Bounias *et al* 1994). Lastly, confectioner's sugar has been used to control mites with some success (Fakhimzadeh 2001).

While it is accepted that there are at least three disadvantages to using specifically formulated miticides, namely cost, possible residues in bee products, and the possible development of pesticide resistance, care should be taken in the use of the alternative treatments. Many of the alternative products are known to be toxic at high levels, and it is not only the directed miticides that result in residues in bee products. Thymol treatment results in residues in wax (Bogdanov *et al* 1998) as well as honey (Lodesani *et al* 1992; Bogdanov *et al* 1998; but not in Imdorf *et al* 1995). Formic acid residues have also been found in honey samples (Hansen & Guldborg 1988) and it is likely that residues from most if not all of the alternative treatments will be found, should these treatments be extensively used. Most importantly, none of the alternative products thus tested have been shown to reliably obtain the level of mite fall necessary for varroa control.

A commonly used alternative in the treatment of varroa is the use of biotechnical methods of control such as removal of infested brood or mite trapping in drone brood that is then removed. These methods can be highly successful and can remove as many as 95% of the varroa in a colony (Boot *et al* 1995a; Van Dung *et al* 1997; Horr 1998; Calis *et al* 1999a), and are favoured in many countries. None of these methods are, however, to be favoured in non-temperate honeybee populations where brood production is continual and where drone brood may be produced for as much as six months of the year, and none are practical for commercial beekeepers.

There has been growing realization that an Integrated Resistance Management (IRM) strategy is needed to control the varroa mite, and that the "pesticide treadmill" can at best bring short-term relief. The long-term strategy to control varroa mites must involve the development of mite-resistant bees or

the use of a natural pest or predator of the mite to eliminate the need for the chemical treatment of colonies. These are the focus of attention in many centres of research (Ball 1997, Erickson *et al* 1998; Kanga *et al* 2003). Characteristics normally selected as a basis for this resistance are the hygienic behaviour of the bees (Boecking 1992; Spivak & Reuter 1998; Danka *et al* 1997; Harris & Harbo 1998; Spivak & Gilliam 1998), said to be important in the balanced relationship between *Varroa destructor* and its natural host *Apis cerana* (Peng *et al* 1987), and the non-reproduction of mites in colonies (Harbo & Hoopingarner 1997). The likely success of this strategy is enhanced by the presence of honeybee populations that exhibit good survival in the absence of chemical varroa control (Rinderer *et al* 1997; Monaco 1997; Österlund 1998). In all these cases, the varroa mite almost eradicated the local honeybee population, which has subsequently shown signs of recovery with varroa-resistant colonies, which are now the focus of breeding efforts. For the present, however, chemical miticides are crucial in sustaining honeybee populations in most parts of the world.

The original recommendation given to beekeepers in South Africa was that no chemical treatment be used until it had be ascertained that varroa would result in honeybee colony collapse, particularly when it became apparent that some countries will in the future prevent importation of bee products from countries using certain varroacidal products. At present only the pyrethroid flumethrin (Bayvarol) and amitraz (Apivar) are registered for varroa treatment in South Africa.

SOUTH AFRICAN HONEYBEES

Biology

Two races (sub-species) of honeybee are found in South Africa. Traditionally, the Cape honeybee (*Apis mellifera capensis*) was a coastal race occurring in the fynbos biome along the southwest and south coasts of South Africa (Hepburn & Crewe 1991), seldom penetrating inland for more than 300km and typically only as far as the mountain ranges bordering the Klein Karoo. The rest of South Africa was the domain of the African or Savanna honeybee (*A.m.scutellata*). [This race of honeybee is termed the Savanna honeybee for the remainder of this thesis, to distinguish it from African honeybees in general; that is, the ten races of honeybee existing in Africa (Hepburn & Radloff 1998)]. A presumably stable hybrid zone is found between the two races, extending between the first and second ranges of the Cape Fold Mountains (Hepburn & Crewe 1991). As the two races appeared to be ecologically out of phase with each other (Hepburn & Jacot Guillarmod 1991) the distribution and integrity of the two races was considered to be stable and assured (Hepburn & Crewe 1991).

In 1990, colonies of the Cape honeybee were moved out of their native range by beekeepers and introduced into the Limpopo Province of South Africa (Allsopp 1993). These Cape honeybee colonies were housed in apiaries containing colonies of the Savanna honeybee, *A. m. scutellata*, which resulted in the invasion of the Savanna honeybee colonies by Cape honeybee workers. In these colonies, Cape workers are able to activate their ovaries and become reproductively active (Allsopp

1993; Martin *et al* 2002; Neumann and Hepburn 2002). Unlike other honeybee subspecies where workers produce males by arrhenotokous parthenogenesis, workers of the Cape honeybee produce female offspring through thelytoky (Onions 1912; Anderson 1963). As a result, the number of Cape workers in the colonies increase, eventually resulting in the death of the Savanna queen and the loss of the colony (Neumann and Hepburn 2002). Yearly, this so-called 'Capensis problem' causes the loss of thousands of commercial Savanna honeybee colonies (Allsopp 1993; Martin *et al* 2002). There is little or no foraging in these colonies, and they soon run out of nectar and pollen reserves. These colonies then dwindle in size to only a few hundred bees, which then either die-out or invade other *scutellata* colonies, thus repeating the cycle. As commercial beekeeping in South Africa is highly advanced, with beekeepers often migrating their colonies hundreds of kilometres for honey-flows or commercial pollination, the Capensis Problem was rapidly spread throughout the formerly-*scutellata* regions of South Africa, to both sedentary and migratory beekeepers. A decade-worth of legislation, research and investigation has yet to reveal full understanding of the mechanics or dynamics of the Capensis Problem, and large-scale colony losses continue to this day.

Cape bee problems appear to be largely restricted to commercial honeybee populations, and have not significantly penetrated the wild honeybee population in conservation areas. Hence, the Cape Honeybee Problem appears not to pose a significant ecological threat. Wild *scutellata* colonies invaded by Cape bees are surely eliminated as readily as are the commercial colonies, but there is no spread of the problem, as the Cape bees disappear as soon as the host colony collapses and dies. It requires the clumping of colonies in apiaries to allow for the Capensis Problem to persist.

It was therefore to a much-changed honeybee and beekeeping landscape that the varroa mite arrived in South Africa in 1997. Cape honeybees were now to be found across the width and breadth of South Africa and commercial *scutellata* colonies were weakened and vulnerable.

Value of honeybees to South Africa

The beekeeping industry is extremely important in South Africa with the use of commercial honeybee colonies for the pollination of a vast array of agricultural crops being valued at more than R4 billion per annum (Table 1.1; 2001 figures). The production of certain crops, such as much of the deciduous fruit produced in the Cape as well as sub-tropical crops in the Lowveld, and the multitude of jobs provided by this agricultural activity, are totally dependent on healthy honeybees for pollination. Most cultivars of apples and pears, as well as some plum cultivars, require intensive honeybee pollination for adequate seed set, and hence fruit production. Some 250 000 direct jobs are to be found in crop production dependent on honeybees for viability. The value of honeybees in the production of subsistence crops in Africa is also inestimable, but surely considerable.

While South Africa has a relatively poor beekeeping tradition, with only very limited traditional beekeeping, the same cannot be said for the Miombo Woodland countries to the north of South Africa. As befitting the continent with the richest archeological record of a human association with honeybees

(Crane 1983), traditional beekeeping is practiced almost throughout the continent using a great variety of hives (Crane 1983). Many thousands, and probably hundreds of thousands, of people in Africa depend on traditional and small-scale beekeeping as part of their livelihood, with much of the wax and honey produced being exported and earning valuable currency (Johannsmeier 2001). The loss of honeybee colonies to the varroa mite in these countries at a scale similar to that witnessed in the USA would result in great losses in this sector. In contrast, commercial beekeeping, both in South Africa and elsewhere in Africa, would be expected to continue much as before, save for additional costs arising from the use of varroacides and increased difficulties in catching honeybee swarms.

Table 1.1: Estimated economic returns from the use of honeybees in commercial crop pollination in South Africa

Crop Type	Hectares*	Annual production (tons)*	Annual value (R million)*	Honeybee Factor**	Honeybee added value (R million)
Deciduous fruit	58 195	1 235 716	2 348.05	0.60 – 0.95	2 058. 85
Berries	1 070	5 137	60.90	0.50 – 0.95	49.56
Nuts	15 350	6 565	89.27	0.50 – 1.00	72.47
Tropical Fruit & Citrus	85 096	1 391 154	1328.99	0.20 – 0.95	666.03
Field crops	479 000	765 432	1 085.40	0.15 – 0.80	116.69
Oilseed crops	845 000	1 133 477	969.67	0.65	523.80
Vegetables	48 300	892 907	1 172.26	0.15 – 0.90	293.95
Seed production	?	?	127.69	0.60 – 0.90	102.15
Other	?	?	1 019.85	0.50 – 0.90	210.30
TOTALS	1 532 011	5 430 388	8 202.08	0.15 – 1.00	4 093.80

* Sources: Statistical Information of the NDA, 2001. Capespan; Key Deciduous Fruit Statistics, 2002; SANSOR; Johannsmeier & Mostert, 2001.

** Honeybee Factor is based on the dependence of the crop on insect pollination, and the proportion of pollinators that are likely to be honeybees (Robinson *et al* 1989; Morse & Calderone 2000; Johannsmeier & Mostert 2001; Allsopp unpublished data).

It is not only beekeepers that are at risk because of the varroa mite. Perhaps the greatest threat of varroa in Africa is to the wild honeybee populations that pollinate as many as 40-70% of indigenous

flowering plants. Should South Africa and the rest of Africa suffer the loss of wild bees witnessed in other parts of the world, this could have significant implications for floral conservation and biodiversity. The contribution made by honeybees to conservation and biodiversity by virtue of their pollination of flowering plants is poorly researched in Africa (Hepburn and Radloff 1998; Rodger and Balkwill 2002), but is sure to be substantial considering the numerical abundance of honeybee foragers. It has been reported that in some regions in Africa as many as 90% of all flowering plants in the region are visited by honeybees (Damblon 1987), and the 407 principal bee plant genera in Africa identified by Hepburn and Radloff (1998) represent some 40% of all plant genera on the continent. The sheer number of plant species visited by honeybees dictates acceptance of their supreme importance as pollinators of indigenous flora. Bees are also an essential pollinator of the fynbos biome. Steiner (1987) calculated that 83% of the fynbos plants are insect pollinated. The effect of a mite-mediated catastrophe to the honeybee population in Africa, in terms of conservation and biodiversity, can only be guessed at but is certain to be considerable.

Other than the direct value of bees from apiculture, and the indirect value of pollination of both commercial crops and indigenous flora, there is an additional value to honeybees in Africa derived from their mythological and often spiritual status. Bees and honey have been valued from earliest times and it is only very recently that practical exploitation has supplanted symbolism (Crane 1983). As evidenced by the vast numbers of rock painting of honeybees, and the host of representations of bees in coins, jewellery, glass and sculpture, honeybees are part of the fabric of man. Nowhere is this more apparent than in Africa (Crane 1983), and nowhere would the loss of honeybees to the varroa mite be more keenly felt.

POTENTIAL IMPACT OF VARROA MITES ON BEEKEEPING & HONEYBEES IN SOUTH AFRICA

After the detection of *Varroa destructor* in South Africa, and on the basis of international evidence, it was decided that there was no prospect of containing the spread of the mite, nor was there a biocontrol agent available that could be used to eliminate varroa. It was accepted that varroa would eventually spread throughout South Africa, and probably throughout sub-Saharan Africa. The time span for this spread in South Africa was estimated to be between 2-7 years (De Jong *et al* 1982), with rapid spread in areas of commercial beekeeping activity and more gradual spread elsewhere. What was not known was what effect it would have on these honeybee colonies, and whether *Varroa destructor* would be as devastating in South Africa as had been the case in other parts of the world.

As the virulence of mite appears to depend on a number of factors, most importantly the strain of bees, it was hoped and expected that *Varroa* would not present the same level of problems in South Africa that it had in Europe and the USA. Previous research has shown that the mite is less virulent in African races of *Apis mellifera* than it is in European races, although the mechanisms for such tolerance are not well understood. The shorter developmental time exhibited by African races appears

to result in a larger degree of infertility in adult mite females after the invasion of worker brood (Camazine 1986; Ritter & De Jong 1984; Ritter *et al* 1990; Rosenkranz & Stürmer 1992: Rosenkranz & Engels 1994; Aumeier *et al* 1996; but not Kirsch & Rosenkranz 1998) or injured or immature male mites (Martin *et al* 1997; Harris & Harbo 1999) thereby keeping the number of mites below the danger threshold and contributing to the relative tolerance of the African honeybee races. The mite is therefore only able to productively reproduce in drone brood, which limits the population growth of the mite. In its original habitat, and with its original host (the Asian honeybee which exhibits an extremely short developmental period), the varroa mite has a balanced parasite-host relationship and does not cause any great damage.

Other suggested contributing factors to mite tolerance in African bees are the reported active defence to varroa of African races of honeybee (Moretto *et al* 1991), said to be similar to that of the natural host *Apis cerana* (Peng *et al* 1987), defence that is largely absent in European races of *Apis mellifera* (Ruttner & Hänel 1992); the better hygienic behaviour in Africanized colonies (Moretto *et al* 1991); and the reduced attractiveness of brood of Africanized bees to varroa mites (Guzman-Novoa *et al* 1996; but not Aumeier & Rosenkranz 1997). Together these are expected to result in higher mite mortality and contribute to mite population levels being kept below danger threshold, and the relative tolerance of African honeybees to varroa.

Varroa infestations appear also to be influenced by environmental (Moretto *et al* 1991) and seasonal (Marcangeli *et al* 1992) conditions. It might be expected that varroa mites are at their most devastating in tropical areas where brood is available throughout the year (De Jong *et al* 1984) but this has not been the case. The mite is most effective under cooler, temperate conditions (Ritter & De Jong 1984; Ritter *et al* 1984; Ruttner et al 1984; Engels *et al* 1986; Woyke 1987; Moretto *et al* 1991; Garcia-Fernàndez *et al* 1995) and less so under more tropical conditions. Conditions in South Africa are more tropical than temperate, and mite population levels may be expected to remain below dangerous levels. The situation in the Cape, a region more temperate and even Mediterranean in climate, might well be more serious. The mite has proved to be extraordinarily virulent in California (Finley *et al* 1996), much of which has climatic conditions very similar to the Cape.

Most South American and some USA researchers have come to the conclusion that African honeybees in Africa will be largely tolerant to varroa and that only a small percentage of honeybee colonies will succumb to the mite, that colonies will become increasingly tolerant and that mite levels will rapidly decrease, and that chemical treatment of colonies will not be necessary (Medina 1998; Erickson *et al* 1998; Ruttner 1991; Moretto *et al* 1991; Büchler 1994; but see Page 1998). The core of this argument stems from the “Brazil situation” where varroa mites have been present for more than twenty years, with the Africanized honeybee population in Brazil seemingly suffering little or no ill effects, without the use of chemical treatments (Moretto *et al* 1991; Rosenkranz & Engels 1994, Moretto *et al* 1995; De Jong 1997). Support for this view comes from data from North Africa where varroa has reportedly been of little importance (Ritter 1990; Ducos de Lahitte *et al* 1998), and from research in Europe on the Cape honeybee (*Apis mellifera capensis*) that indicates considerable

tolerance to varroatosis in this honeybee race (Moritz & Hänel 1984; Moritz & Mautz 1990; Moritz & Jordan 1992). This view would predict that varroa would spread throughout the African honeybee population, but would be little more than an additional arbitrary pest present in the colonies.

Other researchers, notably those from Europe and Asia, are unconvinced by the Brazilian argument, and consider the limited problems suffered by honeybee colonies in Brazil to be more a result of non-virulent varroa than of resistant Africanized honeybees. Of the two haplotypes that are able to reproduce successfully on *Apis mellifera*, one haplotype (Japan-type) is relatively non-virulent and the other haplotype (Korea-type) is extremely virulent (De Guzman *et al* 1998; Anderson & Fuchs 1998; Anderson 2000). In only three places has varroa not caused massive colony losses, these being Japan, Russia and Brazil, and these are the only places the Japan-haplotype has been found. Elsewhere varroa has caused massive colony losses, and in all cases the Korea-haplotype is present. Hence, the alternative explanation to the "Brazil situation" is that it was not the Africanized bees that were tolerant to varroa mites, but rather than the mites were not virulent. This explanation is supported by reports that not only Africanized bees in South America but also European bees were untroubled by varroa (Ruttner 1991; Moretto *et al* 1991; De Jong & Soares 1997) and also by reports that Africanized bees in the USA and central America, exposed to the Korea-type, are collapsing due to the mite (Erickson *et al* 1998; Page 1998; Medina 1998). The alternative view, therefore, is that because it is the Korea-type mite that is present in South Africa, it will cause massive colony mortality, comparable to that found in most parts of the world.

A third possibility to consider is that not only are the race of honeybee and the strain of varroa mite important in predicting the outcome of honeybee-mite interactions, but also what viruses are present in the honeybee population (Ball 1997; Bowen-Walker *et al* 1998). There is considerable evidence that colonies infected with varroa eventually collapse as a result of secondary infections, and of these, viruses activated by the presence of the mites are most important. The outcome of this scenario is impossible to predict as very little is known about the honeybee viruses of South Africa.

SCOPE & AIMS OF THE STUDY

- To monitor the spread of *Varroa destructor* in South Africa, in both commercial and wild honeybee populations;
- To estimate the likely impact of the varroa mite on honeybee populations as well as on the pollination services provided by these populations;
- To determine the population dynamics of varroa mites in South African honeybee populations;
- To determine the whether natural tolerance to the varroa mite infestation is developing in South African honeybees;
- And to develop strategies that, if applied, could best counter the threat posed by *Varroa destructor* in South Africa.

CHAPTER TWO

THE INTRODUCTION AND SPREAD OF VARROA MITES IN SOUTH AFRICA

INTRODUCTION

The passage of varroa around the world has been primarily by the deliberate movement of honeybee colonies and honeybee queens by beekeepers, researchers and development agencies, and secondarily by the accidental movement of bees in ships, aeroplanes and container shipping. By these means the mite has been transported virtually across the globe (Table 2.1). Once present on a new continent, the spread of *Varroa destructor* has, in all cases and continents, been extremely rapid (Matheson 1995). For example, varroa mites were to be found in all USA states by 1992 even though the mite was found in the USA for the first time only in 1987 (Kraus & Page 1995a). In Mexico all colonies were infested by 1996 even though the mite was first found only in 1992 (Medina 1998). Spread is typically correlated with commercial beekeeping activity, in particular, the long-distance migration of honeybee swarms by beekeepers for commercial pollination and to exploit honey-flows.

Once present in a region, saturation dispersal of varroa is rapid with the mite spreading between honeybee colonies through the drifting of foraging bees and drones, the robbing of hives by foraging bees, and by migrating honeybee swarms. This occurs both in commercial honeybee populations and in the wild honeybee population. Kraus & Page (1995b) report that no feral colonies in California were varroa-infested in 1990, but that as many as 75% were infested by 1993.

Varroa jacobsoni (as it was then known) was first detected in South Africa on the 22nd August 1997, during the routine inspection of experimental colonies in Stellenbosch. Varroa has previously been found in Africa only in those countries bordering on the Mediterranean (Table 2.1), disregarding unconfirmed reports from Senegal and Niger (Matheson 1993, 1996). As a result of the considerable threat posed by varroa mites, the National Department of Agriculture commissioned an immediate and comprehensive survey for the mite in the commercial honeybee colonies of South Africa. This survey investigated all regions in South Africa, with an obvious focus on the Western Cape. Thereafter, the monitoring of the spread of the varroa mite in South Africa was by means of *ad hoc* surveys wherein honeybee colonies in areas where the mite had not previously been found were periodically sampled. In addition, beekeepers in these areas were requested to monitor for the mite in their colonies, and to send in samples for analysis.

Table 2.1: First arrival of varroa mites in different parts of the world. From Matheson (1995) and references therein; Grabov 1977; De Jong *et al* 1982; Ruttner 1983; Allsopp *et al* 1997; Van Heen *et al* 1998; Matheson 2000; Calderon *et al* 2000; Çakmak *et al* 2003.

Country	Detection of Varroa	Comments
Europe		
USSR (Primorsky region)	1949	From *Apis cerana* moved into the region
USSR (White Russia)	1964	
Bulgaria	1967	Trading from Russia
Yugoslavia / Poland / Romania	1976	
Germany	1977	From Romania
Greece / Hungary / Czechoslovakia	1978	
Finland	1980	
Italy	1981	
France	1982	
Netherlands	1983	
Switzerland / Austria / Belgium	1984	
Spain / Luxembourg	1985	
Denmark / Sweden	1987	
Portugal	1988	
Great Britain	1992	
Norway	1993	
Ireland	1999	
Americas		
Brazil	1971	From Japan
Paraguay	1975	From Japan
Uruguay / Argentina	1976	
Bolivia	1980	
USA	1987	Entry into Florida
Canada	1989	Bees from the USA
Chile / Mexico / Alaska	1992	
Costa Rica	1998	
Panama	2000	
Africa & Middle East		
Turkey	1977	Bees from Romania
Iran / Libya / Tunisia	1978	Bees from Bulgaria & Romania
Algeria	1981	
Israel	1984	
Saudi Arabia	1987	
Iraq	1988	
Egypt	1989	
South Africa	1997	
Pacific		
Papua New Guinea	1986	
New Zealand	2000	

Subsequent surveys for *Varroa destructor* in South Africa paid particular attention to the presence of the mite in the border regions of the country. Varroa mites have been in North Africa since 1978 (Matheson 1995) but South Africa is their first entry into sub-Saharan Africa. Although the mites are eventually expected to spread throughout the continent, if action can be taken to slow their spread and

to prepare countries for the possible impact of the mite on their honeybee populations and beekeepers, this should ameliorate its impact. To this end, it is obviously important to determine if varroa mites are present in our neighbouring countries, or in the regions of South Africa bordering these neighbouring countries. If the mite is indeed found across South African borders, this might provide strong motivation for the development of a common (regional) approach to dealing with the mite.

A further aspect of the spread of varroa mites in South Africa is the passage of the mites into and through the wild honeybee population. The emphasis in South Africa has always been to focus on the possible impact of the varroa mite on the wild honeybee population, rather than the effect on commercial bees, because of (a) the presumed importance of the wild honeybee population in the pollination of indigenous flora, and hence its conservation; (b) the importance of wild honeybees in providing honeybee colonies for small-scale, subsistence beekeepers in rural areas, of whom there are many tens of thousands in Africa; and (c) the dependence of the commercial beekeepers on renewal from the wild honeybee population. In addition, the true impact of the varroa mite on African honeybees can only be monitored in wild, unmanaged honeybee populations, free from the influences of continual re-infection and stress that are imposed by commercial beekeeping, and free from the effects of acaricides. Any tolerance to the varroa mites that would develop in African bees would be expected to develop in unmanaged honeybee populations. Hence, soon after the mite was found in South Africa, efforts were made to establish a network of varroa-monitoring in protected areas (free from the influences of beekeepers) in South Africa. Only by monitoring the arrival of the mite into honeybee colonies in the conservation areas of South Africa, and by determining the effect of the mite on these colonies, will it be possible to determine the true threat of varroa to floral conservation and biodiversity in Africa.

As varroa mites are expected to spread rapidly throughout Africa, the need for a mite-free honeybee population for research purposes was considered to be a priority. The only suitable site for such a honeybee reservoir in the Western Cape is Robben Island, which has long been associated with honeybee research. Department of Agriculture-funded honeybee research was carried out on the island from the 1960's until the late 1980's, and hence the island has a well-established honey bee population (Anderson 1965). This population was sampled for both tracheal mites [*Acarapis woodi,* first found in South Africa in 1995 (Buys 1995)] and varroa mites to determine the suitability of Robben Island as a reservoir for mite-free Cape honeybees.

Numerous methods have been used to detect and assess varroa mite populations in honeybee colonies. (1) The use of sticky boards below colonies, and the inspection of debris for mites, with or without the use of acaricides (Shimanuki & Knox 2000; Calderone & Lin 2003). (2) Brood examination, typically of drone brood (De Jong *et al* 1982; Shimanuki & Knox 2000). (3) The collection of a sample of worker bees and the separation of varroa mites from this sample by means of alcohol, hot water or ether (De Jong *et al* 1982; Shimanuki & Knox 2000), with the worker bees being sacrificed. (4) The

heating of bees to dislodge mites (Crane 1979). (5) The use of inert dusts such as powdered sugar, wheat flour or talcum powder to dislodge mites from adult bees (Ellis 2000; Fakhimzadeh 2000; Macebo *et al* 2002). The method selected for use was the hot water separation of mites from samples of worker bees, as this method is quick and relatively non-destructive, and because this method proved to be more effective than brood examination.

METHODS & MATERIALS

August/October 1997 Survey

In August-October 1997 a comprehensive survey for varroa mites was conducted in honeybee colonies belonging to commercial and hobbyist beekeepers throughout South Africa. Honeybee colonies belonging to beekeepers in all prominent towns were sampled. Where possible, colonies belonging to at least two beekeepers per town were sampled. The number of colonies sampled at each apiary site varied depending on the beekeeper and on availability, but was typically six colonies per site.

From each of these colonies a sample of approximately 500 worker bees was removed from the brood box, and these bees were stored in a 500ml honey bottle with a perforated lid. When convenient, very hot tap-water was added to the bottle and it was vigorously shaken for twenty seconds. The content of the bottle was poured through a 2000µm sieve (Endicotts Ltd., London) to remove the honeybee bodies and debris. A 53µm sieve (Endicotts Ltd., London) was placed below the first sieve, and served to catch any small particles washed through the top sieve. Large volumes of water were flushed through the two sieves, to ensure that any mites were washed onto the bottom sieve. All varroa mites were then counted. The efficacy of this sampling method was tested by sieving samples that were collected from 45 colonies from an extremely heavily varroa-infested apiary in December 1997 three times in succession, and comparing the results with sampling methods reviewed above.

A sample of sealed drone brood was also removed from each colony when drone brood was present. Forty drone pupae were removed from each piece of comb, and all adult varroa mites present on these pupae or in the cells were then counted. The recent history of all colonies was also noted, if known.

Subsequent surveys for the Presence of *Varroa* mites

A number of *ad hoc* surveys for the presence of mites have been conducted since 1997 to confirm the presence of mites in areas where they had not previously been found. Regions checked for the presence of the varroa mite included: southern Cape and eastern Cape (November 1998 and March 1999); northern Cape (October 1998, March 1999, September 1999) and KwaZulu-Natal (December 1998 and November 1999). All independently submitted beekeeper samples were also analysed for varroa mites, up until September 2002. In all cases the sampling of colonies and the processing of samples was identical to that of the original survey. A large number of colonies in an apiary were often

sampled for mites, as against the six-colony limit of the original survey. It should also be noted that samples of worker bees collected in the National Department of Agriculture-funded "Capensis Survey" in 1998 were also checked for varroa mites, and these results are reported. In this survey, worker samples collected from four colonies per apiary were pooled and then analysed for the presence of varroa mites using the same hot-water method. These apiaries therefore provided only a Yes/No answer for the presence of varroa. Finally, only 500 worker bees were analysed by means of the hot-water sieve method for the presence of varroa mites in these surveys; drone brood was not removed and sampled. This is because the original survey indicated that worker sampling was more comprehensive than was drone sampling in the detection of varroa mites (see Table 2.2).

Efforts were made to sample in neighbouring countries (Mozambique, Zimbabwe and Botswana) for the presence of the varroa mite. This was not possible because of the security situation in Zimbabwe and because of non co-operation from the authorities in Mozambique and Zimbabwe. In 2002, the South African side of the borders of Zimbabwe, Botswana, Swaziland and Mozambique were sampled instead, using commercial apiaries within 20km of each of the borders being sampled as in the original survey.

Survey of the wild honeybee population

Two "Conservation Workshops" were hosted by ARC-Plant Protection Research Institute to discuss the importance of varroa monitoring in conserved areas, and to elicit the support of the conservation authorities of South Africa. Present at these workshops (5th and 12th May 2000) were representatives of the National Department of Agriculture (NDA), the Department of Environmental Affairs & Tourism (DEAT), the South African National Parks Board, and the conservation authorities of seven of the nine provinces (Gauteng, Northern Province, North-West, Free State, Kwazulu-Natal, Western Province, Mpumalanga). All participants at both workshops indicated that they viewed the varroa threat as one of significance, and indicated their willingness to assist and participate, budgetary constraints notwithstanding. As no external funding was available with which to purchase material needed for this monitoring programme, only the conservation departments of Gauteng, Western Cape, KwaZulu-Natal, Mpumalanga and Limpopo provinces were able to participate.

Varroa monitoring was established in seventeen nature reserves in these five provinces. In all cases the procedure followed was the same. Five-frame trap boxes were purchased from beekeepers and placed in the reserves to catch honeybee swarms. Propolis and Nasanov extracts were placed in colonies to attract honeybee swarms to the boxes (Schmidt 1999). Between ten and thirty trap-boxes were established in each reserve, normally in clusters of five. Trap boxes were typically suspended in trees to protect them from baboons, ratels and white rhinoceros, but were placed on stands or existing structures when suitable trees were absent. Clusters of trap-hives were placed in the region of the nature reserve considered to be closest to an area of commercial beekeeping activity. In large reserves, other clusters were placed in regions of the nature reserve most remote from commercial beekeeping activity. After the placement of the trap-boxes, all traps were monitored approximately

every three months. The following data was collected from each trap-hive containing bees during each three-monthly survey: history of the trapped hive, number of bees present, amount of worker brood present and amount of drone brood present, amount of pollen and honey, and the presence of the queen and queen cells. A sample of approximately 500 worker bees was collected and checked for varroa mites using the hot-water method, as described previously.

Robben Island

The honeybee population on the island was comprehensively surveyed with every reported colony being sampled for both varroa and tracheal mites. Varroa mites were sampled as described above, and tracheal mites as described in Shimanuki & Knox (2000), with twenty workers being dissected for each colony sampled. The majority of colonies that were found on the island were removed from their cavities and housed in apiaries established on the island. All hived colonies on the island were sampled approximately every three months for the varroa mite (and sometimes for tracheal mites) from October 1997 until March 2003.

RESULTS

The complete results of the presence of varroa mites in the samples taken from colonies in the August-October 1997 survey and subsequent surveys are presented in Appendix I. Only the results of the worker honeybee samples analysed for varroa mite presence with the hot-water and sieve method are presented. Results of varroa mites in drone brood are not presented, as this sampling method was discontinued after the August-October 1997 Survey.

August – October 1997 Survey

Samples of honeybees were collected from a total of 201 apiaries and 1037 colonies, covering almost all regions of South Africa (Table 2.2). Varroa was found only in the Western Cape, and the distribution of varroa in South Africa at the end of 1997 is indicated in Figures 2.1 and 2.2. The eastern-most distribution of *Varroa destructor* in South Africa at this juncture was Ladismith, and the northern-most Porterville. No varroa mites were to be found in the rest of South Africa.

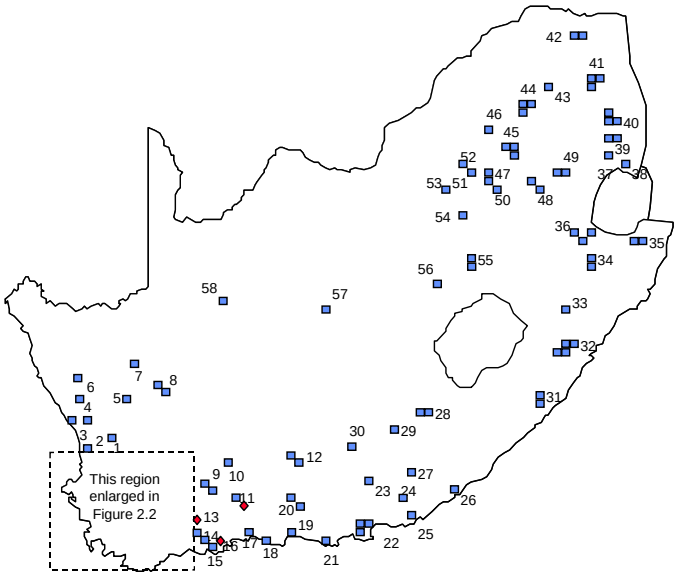
Within the Western Cape, *Varroa destructor* was found to be widespread and common (Figure 2.2; Appendix I). In the Western Cape proper, delimited by Malmesbury, Wellington, Villiersdorp and Grabouw, 84% of all apiary sites and 56% of all honeybee colonies sampled had varroa mites (Figure 2.2; Table 2.2). In those regions adjacent to the above delimitation of the Western Cape where varroa is found, there are lower numbers of varroa per infected colony, and lower numbers of infected colonies per infected apiary, in comparison to the Western Cape proper (Table 2.2; Appendix I), indicating recent infestation and confirming Cape Town as the source of varroa mite introduction into South Africa. Beyond this region, and extending through the rest of South Africa, varroa mites were absent.

Surprisingly large numbers of mites were found in some apiary sites in the Cape, with a total of 911 varroa mites from worker samples being found, at a mean of 6.8 varroa per worker sample (Table 2.2). The largest number of varroa mites found in a worker sample was 141, and 127 varroa in a drone sample from 40 cells, both indicating a relatively high level of varroa infestation in the Western Cape.

Table 2.2: First survey for *Varroa* in South Africa, August-October 1997. A sample of approximately 500 worker bees was removed from the brood box of each colony sampled, and analysed for varroa mites using soil sieves and hot water. Where sealed drone brood was present, 40 sealed drone cells were opened and checked for the presence of varroa mites.

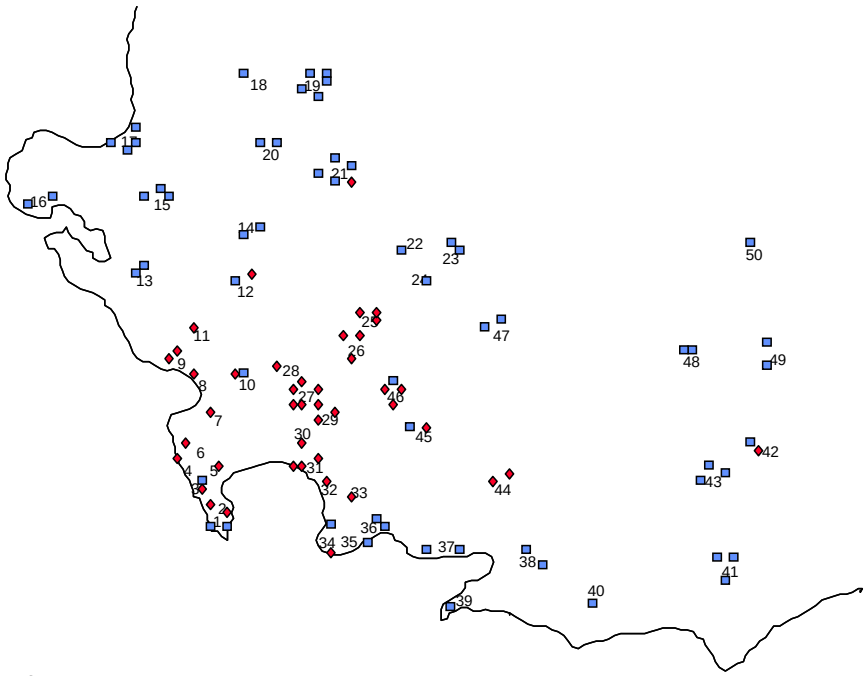
	Western Cape*	**Rest of SA**	**Total**
Number of apiary sites surveyed	45	156	201
Number of apiary sites with *Varroa*	38	8	46
Percentage of apiary sites with *Varroa*	84	5	23
Number of honeybee colonies surveyed	260	777	1037
Number of honeybee colonies with *Varroa*	134	15	149
Percentage of honeybee colonies with *Varroa*	52	2	14
Number of honeybee colonies in infected apiaries	218	48	266
Number of honeybee colonies with *Varroa i*n infected apiaries	134	15	149
Percentage of honeybee colonies with *Varroa* in infected apiaries	61	31	56
Number of worker samples analysed	260	777	1037
Number of honeybee colonies with *Varroa* present in the worker sample	126	14	140
Total number of *Varroa i*n worker samples	911	40	951
Average number of *Varroa* in worker samples of infected colonies	6.8	2.7	6.4
Maximum number of *Varroa* in a worker sample	141	10	141
Number of drone samples analysed	85	314	399
Number of honeybee colonies with *Varroa* present in the drone sample	31	2	33
Maximum number of *Varroa* in a drone sample	127	22	127
Varroa in worker sample & *Varroa* in drone sample	23	1	24
Varroa in worker sample & no *Varroa* in drone sample	15	0	15
Varroa in drone sample & no *Varroa* in worker sample	8	1	9

* Western Cape delimited by Malmesbury, Wellington, Villiersdorp and Grabouw



1 - Clanwilliam; 2 - Graafwater; 3 - Lamberts Bay; 4 - Vredendal; 5 - Vanrhynsdorp; 6 - Koekenaap; 7 - Nieuwoudtsville; 8 - Calvinia; 9 - Matjiesfontein; 10 - Laingsburg; 11 -Ladismith; 12 - Beaufort West; 13 - Barrydale; 14 - Heidelburg; 15 - Witsand; 16 - Vermaaklikheid; 17 - Stilbaai; 18 - Gouritsriviermond; - 19 - George; 20 - Oudtshoorn; 21 - Plettenberg Bay; 22 - Port Elizabeth; 23 - Somerset East; 24 - Grahamstown; 25 - Port Alfred; 26 - East London; 27 - Fort Beaufort; 28 - Queenstown; 29 - Cradock; 30 - Graaff-Reinet; 31 -Harding; 32 - Richmond; 33 - Greytown; 34 - Vryheid; 35 - Pongola; 36 - Piet Retief; 37 - Nelspruit; 38 - Malelane; 39 - White River; 40 - Hoedspruit; 41 - Tzaneen; 42 - Louis Trichardt; 43 - Nylstroom; 44- Warmbaths; 45 - Pretoria; 46 - Skeerpoort; 47 - Roodepoort; 48 - Heidelburg; 49 - Evander; 50 - Boons; 51 - De Deur; 52 - Derby; 53 - Ventersdorp; 54 - Parys; 55 - Arlington; 56 - Winburg; 57 - Douglas; 58 - Kakamas.

Figure 2.1: Distribution of apiary sites in South Africa where colonies were sampled in October 1997 for the presence of varroa mites. Legend: ■ Apiary without *Varroa*. ◆ Apiary with *Varroa*



1 - Cape Point; 2 - Smitswinkelbaai; 3 - Noordhoek; 4 - Houtbaai; 5 - Tokai; 6 - Rosebank; 7 - Parow; 8 - Tableview; 9 - Melkbosstrand; 10 - Durbanville; 11 - Philadelphia; 12 - Malmesbury; 13 - Darling; 14 - Moorreesburg; 15 - Hopefield; 16 - Saldanha; 17 - Veldrif; 18 - Het Kruis; 19 - Citrusdal; 20; Piketburg; 21 - Porterville; 22 - Tulbagh; 23 - Ceres; 24 - Wolseley; 25 - Wellington; 26 - Paarl; 27 - Koelenhof/Klapmuts; 28 - Kraaifontein; 29 - Stellenbosch; 30 - Vlottenberg; 31 - Somerset West/Strand; 32 - Gordon's Bay; 33 - Grabouw; 34 - Pringle Bay; 35 - Betty's Bay; 36 - Kleinmond; 37 - Hermanus; 38; Stanford; 39 - Gansbaai; 40 - Elim; 41 - Bredasdorp; 42 - Swellendam; 43 - Riviersonderend; 44 - Caledon;45 - Villiersdorp; 46 - Franschhoek; 47 - Worcester; 48 - Robertson; 49 - Montagu; 50 - Touwsrivier.

Figure 2.2: Distribution of apiary sites in the Western Cape where colonies were sampled in October 1997 for the presence of varroa mites. Legend: ■ Apiary without *Varroa*. ◆ Apiary with *Varroa*

On 15 occasions the worker sample of a colony had varroa mites whilst the drone sample of the same colony did not, compared to the 8 occasions when the drone sample had mites and worker sample did not (Table 2.2). This suggests that the worker sampling method is slightly more sensitive, and given that this method is both simpler and less destructive, the drone sampling was discontinued in subsequent sampling.

To determine the efficacy of the worker sample and hot-water method of detecting varroa mites, samples of approximately 500 worker bees were collected from the brood boxes of 45 colonies in a heavily infested apiary. Each sample was sieved three times, and it was found that 98% of all mites detected were collected during the first sieving (Table 2.3). Only 0.05% of mites were collected during the third repetition, confirming the efficacy of the procedure.

Subsequent surveys & *ad hoc* sampling

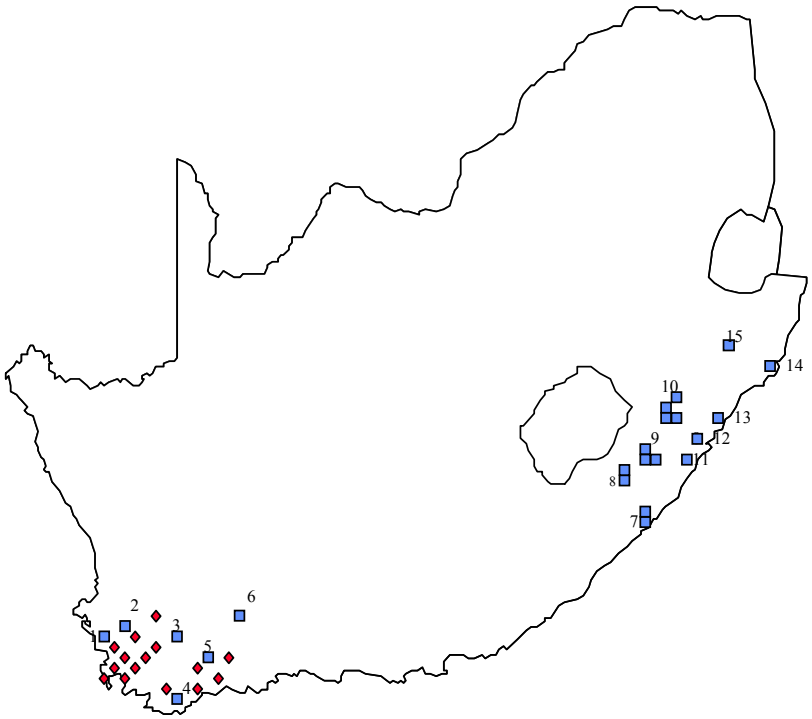
At the end of 1997 the varroa mite was to be found only in the Western Cape (Table 2.1). Subsequent surveys and beekeeper submitted samples during 1998 indicated that the distribution of the mite was slowly expanding in the Western Cape to include Darling, Moorreesburg, Worcester, Elim, Riviersonderend and Touwsrivier (Figure 2.3; Appendix I). Areas surveyed that remained free of the mite included the Karoo (Laingsburg, Matjiesfontein, Prince Albert, Beaufort West), Northern Cape, Eastern Cape, Free State, Gauteng, Mpumulanga and Limpopo (Figure 2.3; Appendix I). The big surprise was the arrival in huge numbers of *Varroa destructor* in Kwazulu-Natal. The first report of the mite in the province was from both Eston and Babanango in September 1998. A comprehensive survey revealed that the mite was present almost throughout Kwazulu-Natal (Figure 2.3). Interestingly, the mite was present in massive numbers in the Natal Midlands (Richmond, Hilton, Pietermaritzburg) but only present in low numbers along the coast (Margate, Amanzimtoti, Durban, Umdloti Beach, Richards Bay) (Appendix I).

A number of small surveys were carried out in 1999, and a number of beekeeper-submitted samples were analysed. By the end of 1999 the distribution of varroa mites in South Africa had expanded to include the West Coast (Saldanha, Veldrif, Hopefield, Citrusdal, Clanwilliam), the Southern Cape and Klein Karoo (Robertson, Langkloof) and south-east Gauteng (Heidelberg, Vanderbijlpark, Johannesburg) (Figure 2.4; Appendix I). The arrival of the mites in Gauteng could be traced to the movement of honeybee colonies from Richmond in Kwazulu-Natal to Heidelburg, Gauteng in December 1998. Samples collected from the Northern Cape, Mpumulanga, Eastern Cape and Free State in 1999 failed to indicate the presence of *Varroa destructor*.

Samples and surveys for varroa mites were continued during 2000 – 2002. In 2000 the mite was found in the Central Karoo (Beaufort West), the North-East Cape (Douglas), the Eastern Cape (Grahamstown), Mpumalanga, Central Free State, and Northern Gauteng (Figure 2.5; Appendix I). The arrival of the mite in the Eastern Cape was almost certainly due to the movement of bees to Grahamstown from Pretoria and Douglas.

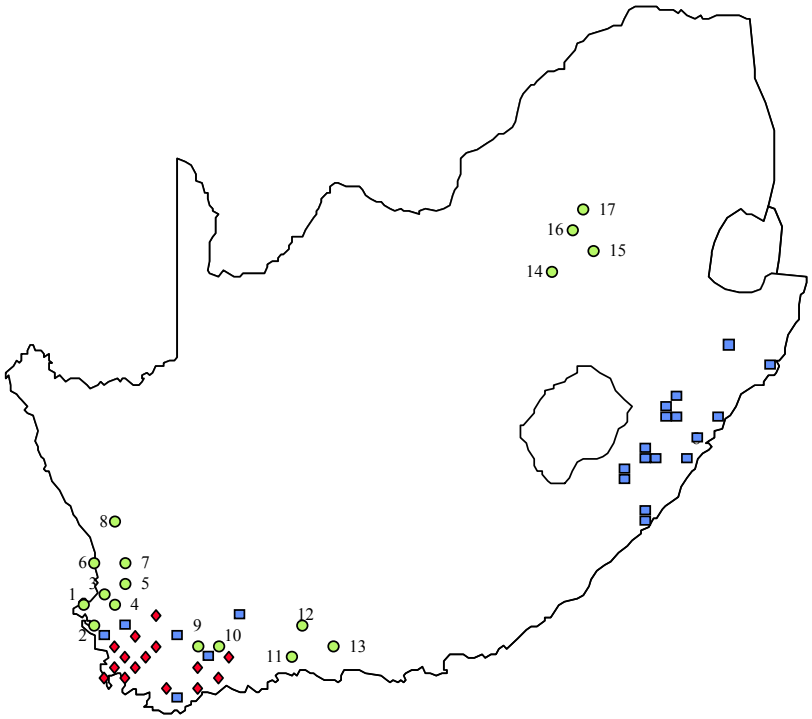
Table 2.3: Evaluation of the efficacy of the soil-sieve/hot water method for analysing worker honeybee samples for varroa mites. Samples from extremely heavily infested colonies were sieved repeatedly to determine the percentage of mites missed during a single sieving (= standard procedure). Samples were from approximately 500 worker bees collected from the brood box of colonies.

Colony Number	Varroa mites on 1st sieve	Varroa mites on 2nd sieve	Varroa mites on 3rd sieve	Total number of varroa mites
1	116	1	0	117
2	15	1	0	16
3	125	3	0	128
4	68	1	0	69
5	112	2	0	114
6	88	0	0	88
7	62	0	0	62
8	5	0	0	5
9	20	2	0	22
10	106	0	0	106
11	95	2	0	97
12	90	1	0	91
13	56	0	0	56
14	103	0	0	103
15	35	3	0	38
16	102	1	0	103
17	139	1	0	140
18	145	1	0	146
19	105	0	0	105
20	21	0	0	21
21	35	0	0	35
21	43	4	0	47
23	103	11	0	114
24	223	2	0	225
25	64	0	0	64
26	62	0	0	62
27	45	0	0	45
28	69	5	1	5
29	60	1	0	61
30	58	0	0	58
31	6	0	0	6
32	8	0	0	8
33	42	0	0	42
34	44	1	0	45
35	3	0	0	3
36	52	0	0	52
37	129	2	0	131
38	53	1	0	54
39	85	0	0	85
40	79	4	0	83
41	58	1	0	59
42	145	3	0	148
43	314	11	0	325
44	233	5	1	239
45	109	6	0	115
Total number of varroa mites	3842	76	2	3920
Percentage of total mites counted	98.01	1.94	0.05	100.00



1 – Darling; 2 – Moorreesburg; 3 – Worcester; 4 – Elim; 5 – Riviersonderend; 6 – Touwsrivier; 7 – Margate; 8 – Highflats/Ixopo; 9 – Richmond; 10 – Pietermaritzburg/Hilton; 11 – Amanzimtoti; 12 – Durban; 13 – Umdloti Beach; 14 – Richards Bay; 15 – Babanango.

Figure 2.3: Spread of the varroa mite in South Africa in 1998. Areas where varroa was first found in 1998 indicated by a ■; areas where varroa was found in 1997 indicated by a ◆.

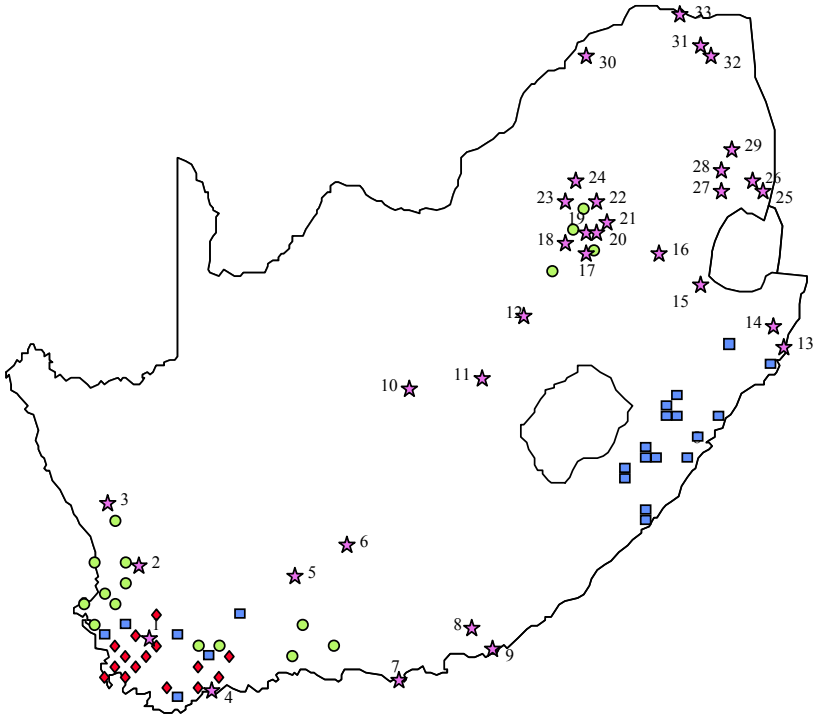


1 – Saldanha; 2 – Atlantis; 3 – Veldrif; 4 – Hopefield; 5 – Citrusdal; 6 – Lamberts Bay; 7 – Clanwilliam; 8 – Lutzville; 9 – Robertson; 10 – Montagu; 11 – Albertinia; 12 – Ladismith; 13 – Langkloof; 14 – Vanderbijl Park; 15 – Heidelberg; 16 – Johannesburg; 17 – Pretoria.

Figure 2.4: Spread of the varroa mite in South Africa in 1999. Areas where varroa was first found in 1999 indicated as ●; areas where varroa was first found in 1998 indicated by a ■; areas where varroa was first found in 1997 indicated by a ◆.

In 2001 the mite was detected in the Northern Cape, and in 2002 in the Limpopo Province, Northern Kwazulu-Natal and in North-West Province (Figure 2.5; Appendix I). At this stage *Varroa destructor* had been found in all nine provinces in South Africa, and in all major regions of the country.

Included in the surveys of 2002 was an attempt to determine whether the varroa mite had crossed into neighbouring countries. Due to bureaucratic inertia and political upheaval, it was not possible to sample along the borders between South Africa and Zimbabwe, Mozambique and Botswana, nor in these countries themselves. Apiaries were, however, found in South Africa within 20km of the borders of Mozambique, Swaziland, Botswana and Zimbabwe, at Komatipoort, Piet Retief, Swartwater and Beit Bridge respectively. Varroa mites were found in all of these apiaries, confirming the distribution of varroa in South Africa to be virtually countrywide, and making it extremely likely that the mite was present in our neighbouring countries (Figure 2.5).



1 – Jonkershoek; 2 – Cederburg; 3 – Koekenaap; 4 – De Hoop; 5 – Leeu Gamka; 6 – Beaufort West; 7 – Tsitsikamma; 8 – Grahamstown; 9 – Port Alfred; 10 – Douglas; 11 – Bloemfontein; 12 – Kroonstad; 13 – St Lucia; 14 – Mkuze; 15 – Piet Retief; 16 – Ermelo; 17 – Suikerbosrand; 18 – Alberton; 19 – Springs; 20 – Benoni; 21 – Boksburg; 22 – Rayton; 23 – Brits; 24 – Leeufontein; 25 – Komatipoort; 26 – Crocodile Bridge; 27 – Nelspruit; 28 – White River; 29 – Numbi; 30 – Swartwater; 31 – Louis Trichardt; 32 – Levuvhu; 33 – Beit Bridge.

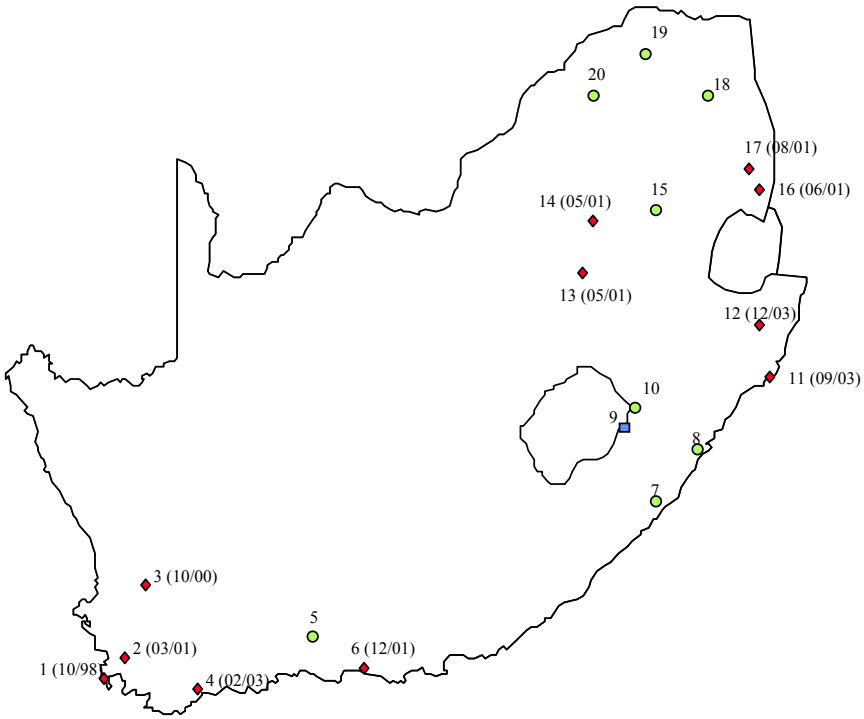
Figure 2.5: Spread of the varroa mite in South Africa in 2000-2002. Areas where varroa was first found in 2000-2002 indicated as ★; areas where varroa was first found in 1999 indicated as ●; areas where varroa was first found in 1998 indicated by a ■; areas where varroa was first found in 1997 indicated by a ◆.

Survey of the wild honeybee population

Trap-hives were established in seventeen nature reserves in five provinces in South Africa, those provinces being Gauteng, Limpopo, Mpumalanga, Western Cape and Kwazulu-Natal. In addition, trap-hives were monitored for varroa mites on the southern and western borders of the Kruger National

Park, as well as in the Tsitsikamma National Park. The distribution of these reserves is indicated in Figure 2.6.

Due to funding and bureaucratic difficulties, a number of the nature reserves were only able to establish their trap-hives in 2003 and 2004, and these hives have yet to trap any honeybee swarms. Of the twenty reserves or regions, honeybee swarms have presently been trapped in twelve (Figure 2.6); of these twelve, varroa mites have been found in all except one (Lotheni Nature Reserve).



1 – Cape of Good Hope; 2 – Jonkershoek; 3 – Cederberg; 4 – De Hoop; 5 – Kammanassie; 6 – Tsitsikamma; 7 – Vernon Crookes; 8 – Kenneth Stainbank; 9 – Lotheni; 10 – Kamburg; 11 – Charters Creek; 12 – Mkuze; 13 – Suikerbosrand; 14 – Leeufontein; 15 – Loskop Dam; 16 – Crocodile Bridge; 17 – Numbi; 18 – Hans Merensky; 19 – Langjan; 20 – D'Nyala.

Figure 2.6: Spread of the varroa mite into conservation regions of South Africa. Trap-hives without varroa indicated as ■; trap-hives with varroa indicated as □; trap-hives that have not trapped any honeybee swarms indicated as ●. Figures in brackets are the months and year that varroa mites were first found in that conservation site.

Robben Island

All wild honeybee colonies that could be found on Robben Island in October 1997, February 1998 and September 1998 were sampled for both varroa and tracheal mites. Neither species of mite was found in any honeybee colony (Table 2.4). An apiary was established on the island in November 1998 and stocked with colonies trapped on the island, or removed from buildings or trees on the island. All colonies were regularly sampled for the presence of either species of mite. A second apiary was established in October 2002 and these colonies were also sampled for the mites. In total, all colonies were sampled for varroa mites on seventeen occasions between November 1998 and March 2003. No varroa mites were found in any colony during this period (Table 2.4). The same colonies were

sampled for tracheal mites on ten occasions during this same period and no tracheal mites were found (Table 2.4).

Table 2.4: Sampling for varroa and tracheal mites in Robben Island honeybee colonies.

Date	Colonies sampled	Total number of varroa mites found in a sample of ±500 bees collected from each colony	Number of bees found with tracheal mites in a sample of 20 bees per colony
October 1997	5 wild	0	0
February 1998	2 wild	0	0
10/09/98	3 wild	0	0
24/11/98	7 hived	0	0
28/1/99	7 hived	0	0
22/2/99	6 hived	0	0
19/4/99	6 hived	0	0
5/8/99	4 hived	0	0
30/9/99	5 hived	0	0
12/12/99	7 hived	0	0
31/03/00	8 hived	0	Not sampled
16/05/00	7 hived	0	0
23/6/00	8 hived	0	Not sampled
14/9/00	8 hived	0	0
23/01/01	9 hived	0	Not sampled
13/04/01	8 hived	0	0
12/09/01	8 hived	0	Not sampled
15/04/02	8 hived	0	Not sampled
24/10/02	9 hived (two sites)	0	Not sampled
26/03/03	8 hived (two sites)	0	Not sampled

DISCUSSION

The detection of *Varroa destructor* in Stellenbosch in August 1997 represented the first arrival of this serious parasite of honeybees in sub-Saharan Africa (Matheson 1995). The comprehensive survey conducted in September and October 1997 confirmed the site of introduction in South Africa to be Cape Town (Figure 2.1; Appendix I; Allsopp 1998). Furthermore, the distribution of the varroa in the Western Cape at this time provides some room for speculation as to the source of varroa infestation, and how long the mite had been present. All colonies belonging to beekeepers on the western seaboard (Noordhoek, Hout Bay, Tableview) were heavily infested with varroa, much more so than in other regions of the Peninsula (Appendix I). This suggests this region as the point of origin of the mite; as a consequence, the possibility of varroa arriving in South Africa in a ship-borne swarm is considered most likely.

The level of varroa infestation in 1997 suggested the presence of the mite for at least three years, the same period of time varroa mites were present in the United Kingdom before detection (Martin 1997a). It is likely, however, that varroa only reached the Boland and hives belonging to commercial beekeepers in 1997. This can be deduced by virtue of colonies on the west coast and the southern Cape being essentially free of varroa at the end of 1997, despite the fact that a number of beekeepers from these regions annually migrate large numbers of colonies to the Boland for pollination, where they mingle with Boland beekeepers. These Boland beekeepers, without exception, have varroa in their colonies, and the fact that colonies of the more removed beekeepers were varroa-free at this time indicates that the Boland beekeepers' colonies only suffered from varroa infestation during 1997. If the infestation had been earlier, colonies of beekeepers from the west coast and south Cape would have been infested during the 1996 pollination season (August to October). The beekeepers represented by all sites outside the Cape Peninsula and the Boland where varroa was found, namely Vermaaklikheid, Barrydale, Ladismith, Swellendam, Betty's Bay and Porterville, had all moved colonies from the Cape Peninsula or the Boland to these sites in the past 12 months. Prior to this, it is likely that these sites were free of varroa. The percentage of infected colonies in affected apiaries and absolute numbers of varroa in these regions is lower than that of the Western Cape (Table 2.2), indicating recent infestation.

While the distribution of the mite in South Africa was found to be limited to the Western Cape in the 1997 survey, it was widespread and common in managed honeybee colonies (Figures 2.1 & 2.2). The widespread nature of varroa mites in the Cape, the relative abundance of mites in infected colonies, and the fact that most beekeepers are not registered and do not belong to any controlled association made any eradication of varroa in South Africa practically impossible, and no attempt was made to eradicate or quarantine the mite. Attempts to eradicate varroa have failed wherever they have been tried, as have attempts to quarantine the mite within a country or region (Matheson 1995; Martin 1997a; Matheson 2000). Varroa was expected to spread throughout South Africa, and eventually throughout sub-Saharan Africa, primarily through the action of beekeepers. The traditional long distance movement of colonies for pollination and honey production enables the mite to spread rapidly over long distances (Martin 1997a).

Subsequent surveys for the varroa mite, and the analysis of beekeeper-submitted samples, confirmed both the rapid spread of the mite and the dependence on human activities for this spread. In 1998 the mite was found to be absent from the southern and eastern Cape, but mysteriously appeared in Kwazulu-Natal, some 1200 km from the most eastward distribution of the mite in the Western Cape. It has been suggested that this represented a second and independent arrival of *Varroa destructor* into South Africa. Three factors argue against this conclusion: (1) In 1998 the mites were found at an extremely high density in the Kwazulu-Natal midlands (Richmond, Pietermaritzburg) and only in very low numbers along the coast (Appendix I). The accidental arrival of the mite in Durban, by aeroplane or ship, and subsequent spread through the province is not supported by these data. (2) The mites

found in Kwazulu-Natal and Western Cape were found to represent a single population (Anderson & Trueman 2000; D Anderson pers. comm.); (3) It is very unlikely that varroa mites should accidentally be discharged in Cape Town in 1997, and then again in Durban in 1998, given that the mite had not appeared in the country in the previous 25 years. A single introduction and subsequent spread is a much more parsimonious explanation.

Consequently, it is highly likely that the spread of the varroa mite from the Western Cape in 1997 to Kwazulu-Natal in 1998 was human assisted, and was most likely caused by beekeepers moving Cape honeybees to Kwazulu-Natal in an attempt to counteract the Cape Honeybee Problem (Allsopp 1993). It should be noted that this passage of honeybees would have been illegal in terms of the Agricultural Pests Act (Act 36 of 1983), amendment R159 of 5th February 1993. Nonetheless, this is considered to be the most likely source of varroa mites in Kwazulu-Natal.

The passage of varroa mites to Gauteng was also due to the activities of beekeepers, with varroa-infested colonies being moved to Heidelburg from Richmond in Kwazulu-Natal in December 1998 (Appendix I). These varroa-infested colonies were unfortunately taken to the aloes in Limpopo province in June 1999, an area and circumstance where very large numbers of honeybee colonies are deposited in close proximity to each other, and this was the source of further spread of the mite. All of this spread of honeybee colonies and the mite was completely legal, and due to normal operating practices of commercial beekeepers. The passage of varroa into the Eastern Cape, free from the mite until 2000, does not fall into this category. Varroa was almost certainly introduced into the Eastern Cape by researchers who transported colonies to Grahamstown from Pretoria and from Douglas. The mite rapidly spread into commercial colonies from these research colonies. It is fair conclusion, therefore, that the rapid spread of the varroa mite in South Africa was due to the activities of beekeepers and bee researchers, as has been the case in the spread of the mite across the globe (Table 2.1; Matheson 1995). It should be noted that the “natural” spread of the mite in South Africa was comparatively slow, with varroa only being detected in isolated areas in the Western Cape such as Jonkershoek some four years after the arrival of the mite in the Cape.

In any event, and as expected, the varroa mite was confirmed to have spread throughout South Africa within five years of its first discovery (Figure 2.5). This rate of spread is consistent with what has occurred in other parts of the world (Kraus & Page 1995a; Martin 1997a; Matheson 2000). Included in this spread has been the arrival of the mite in honeybee colonies adjacent to our neighbouring countries such as Zimbabwe, Botswana, Mozambique and Swaziland (Figure 2.5), or the transport of varroa-infested colonies to these borders. It is inconceivable, considering the typically rapid spread of the mite, that varroa has not crossed into these countries, and that it will not soon be found in the managed honeybee colonies in these countries. Indeed, varroa mites have subsequently been found in Botswana, Swaziland, Zimbabwe and Mozambique (K. Ngakane pers. comm.; M. Schmolke pers. comm.; J. Alcobia pers. comm.) and it is very likely that *Varroa destructor* is already present in most SADC countries. Further spread of the mite throughout these countries, and thereafter to all countries

in sub-Saharan Africa is certain, although this spread is likely to be relatively slow due to the undeveloped beekeeping industries in most of these countries.

The varroa mite was found in all but one of the nature reserves in which honeybee swarms were caught in trap-hives placed there to monitor the spread of the mite through the wild honeybee population (Figure 2.6). This monitoring network has not been as extensive or intensive as was originally planned, but is sufficient to establish that the mite has successfully penetrated the wild honeybee population across much of South Africa (Figure 2.6). Although the long-distance movement of the mite, and the rapid movement of the mite, is due to the actions of beekeepers and bee researchers, once in an area varroa can clearly be expected to spread throughout the honeybee population, both managed and wild, within a reasonably short order of time. Consequently, all honeybee colonies in South Africa (and, in the fullness of time, in sub-Saharan Africa) are expected to be infested with the varroa mite.

The possible ecological, economic and social consequences of the spread of the varroa mite in South Africa are alarming. The value added to crop production by the commercial pollination of honey bees has been estimated to be in the order of R3.2 billion per annum (Table 1.2; 1998 figures). It is also worth noting that this agricultural output sustains some 250 000 jobs. However, and in contrast to the Americas, perhaps the greatest threat of varroa in Africa is to the wild honeybee population. The contribution made by honeybees to conservation and biodiversity by virtue of their pollination of flowering plants is poorly researched in Africa (Hepburn and Radloff, 1998; Rodger and Balkwill, 2002), but is sure to be substantial considering the numerical abundance of honeybee foragers. It has been reported that in some regions in Africa, as many as 90% of all flowering plants in the region are visited by honeybees (Damblon, 1987), and the 407 principal bee plant genera in Africa identified by Hepburn and Radloff (1998) represent some 40% of all plant genera on the continent. The sheer number of plant species visited by honeybees dictates acceptance of their supreme importance as pollinators of indigenous flora. Should South Africa and the rest of Africa suffer the loss of wild bees witnessed in other parts of the world, this could have significant implications for floral conservation and biodiversity. In addition, the potential impact of the varroa mite on small-scale, subsistence beekeeping in south-central and central African countries is enormous. In Africa, and particularly in the more remote parts of Africa, the overwhelming majority of honeybees are wild bee colonies, which could potentially die as a result of varroa infestation, or colonies maintained in traditional hives by small-scale rural beekeepers, these being equally vulnerable to the mite. Should the honeybee population be damaged due to varroa, the spectre of massive ecological damage including the possible loss of plant species due to the lack of adequate pollination is not inconceivable, with possible consequent loss of animal species. The real threat of the varroa mite in Africa is to floral conservation and biodiversity, and to the tens of thousands of beekeepers in Africa than depend on a few honeybee colonies for a substantial part of their livelihood.

For any further surveys for varroa in honeybee populations in South Africa or elsewhere in Africa, it is recommended that only worker samples and not drone samples be collected. The data in Table 2.2 indicate that where both workers and drone brood was sampled from a colony, varroa was found in the worker sample 81% of the time, as against only 69% of the time in the drone sample. As collecting and analysing drone samples is time consuming and destructive, it is suggested that it be omitted from further surveys. Furthermore, the method used to determine the numbers of mites present in a worker sample was shown to be highly effective (Table 2.3) with 98% of mites present in the sample being detected. This success rate compares favourably with the alcohol method (De Jong *et al* 1982), the ether roll method (Shimanuki & Knox 2000), the powdered sugar method (Ellis 2000) and the heating method (Crane 1979), none of which report a recovery of more than 90% of mites. The hot water method has the added advantages of being cheap, easy and relatively non-destructive.

Finally, the honeybee population of Robben Island is confirmed to be free of both varroa and tracheal mites (Table 2.6). Because honeybees were regularly introduced onto the island in the 1980's and early 1990's, this confirms that both species of mite are recent visitors to South Africa. On the basis of this finding, and through the efforts of the Directorate of Plant and Quality Control of the National Department of Agriculture, Robben Island was declared a honeybee sanctuary by Amendment No. R458 of the Agricultural Pests Act, 1983 (Act no. 36 of 1983) on 12th May 2000. The purpose of the amendment was to retain the honeybee population on Robben Island as a mite-free reservoir, for research breeding purposes. To maintain the reservoir it is important to prevent the passage of honey bees or beekeeping equipment to the island. The island-staff are well-informed about not allowing bees to be brought to the island, and the establishment of a permanent beekeeping centre on the island has eliminated the need for regularly taking equipment to the island, thus greatly limiting the risk of pest introduction.

CHAPTER THREE

THE IMPACT OF VARROA MITES IN SOUTH AFRICA

INTRODUCTION

The impact of varroa mites on honeybee populations around the world has been extremely variable, with the reasons for this variability being poorly understood. The majority of unmanaged varroa-infested colonies in California (Kraus & Page 1995b; Finley *et al* 1996) and Arizona (Loper 1996) collapsed and died within a year, as have most untreated colonies in Europe and America (Bailey & Ball 1991; Finley *et al* 1996; Hunt 1998). Losses of more than 100 000 colonies have been reported for Argentina (Dietz 1986), 300 000 for Spain (Gomez Pajuelo 1988) and 2 000 000 for Poland (Hartwig 1994). In more tropical climates, however, honeybee colonies have often persisted for years after varroa infestation without treatment (Ritter 1990; De Jong 1997). The virulence of the mite appears to depend on a number of factors, most importantly the strain of bees, with African honeybees often considered to be largely tolerant to varroa (Medina 1998; Erickson *et al* 1998), environmental (Moretto *et al* 1991) and seasonal (Marcangeli *et al* 1992) conditions, and the presence of secondary pathogens activated by the presence of the mites, particularly viruses (Ball 1997; Bowen-Walker *et al* 1998).

The time taken for colonies to collapse from varroa mites is also extremely variable, being as rapid as six months (Martin 1997a) or as long as seven years (De Jong *et al* 1982). Most colonies are expected to die 1-2 years after infestation begins (Bailey & Ball 1991). There is no clear correlation between mite number and mortality (Martin 1997a). Some colonies die with as few as 2 000 mites while others withstand 25 000 mites; the number of mites in a colony is a poor indicator of colony survivorship (Martin 1998). Notwithstanding the variability as regards varroa numbers and colony collapse, it remains important to have as accurate an approximation of the mite threshold for colony collapse as possible, as a means for commercial beekeepers to determine the economic thresholds for varroacide treatments (Delaplane & Hood 1999), in an effort to prevent pesticide overuse and resistance development (Watkins 1996; Allsopp 2001a). Economic thresholds for varroa collapse in the USA are considered to be 3 100 to 4 200 mites per colony (Delaplane & Hood 1999). In Spain colonies are reported to collapse with mite populations from 2 000 to 15 000 (Bermajo & Fernádez 1997), and in the United Kingdom some colonies have not collapsed with as many as 25 000 mites (Martin 1998).

Despite all the honeybee colonies lost due to varroa mites throughout the world, the proximate reasons behind sudden colony collapses are little understood. Colonies about to collapse from varroa mites frequently do not differ significantly from healthy or treated colonies (Martin *et al* 1998). They typically appear completely normal and damage when it occurs appears suddenly. When a colony does die from varroa, however, it is almost invariably with a very rapid loss of bees and with increasingly patchy brood (Martin 1997a). There are never dead bees remaining in the colony, and often all that remains is the queen and a small handful of worker bees.

The feeding by *Varroa* on juvenile honeybees during the mites' reproductive phase is known to have a host of negative effects, especially when multiple mites are present in a single brood cell. These include a reduced adult weight (De Jong *et al* 1982), deformed wings and abdomens, a decrease of protein and carbohydrate levels in the haemolymph (Weinburg & Madel 1985), and the degeneration of fat bodies and smaller hypopharyngeal glands (Schneider & Drescher 1987; Schatton-Gadelmayer & Engels 1988; Fries *et al* 1994; Amdam *et al* 2004). These physiological changes in turn can lead to a reduction in adult emergence, an early onset in foraging, reduced flight capacity, a decrease in the capacity to overwinter and a reduced lifespan (De Jong *et al* 1982; DeJong & DeJong 1983; Kovac & Crailsheim 1988; Beetsma *et al* 1989; Fries *et al* 1994; Rinderer *et al* 1999; Amdam *et al* 2004), and an increase in pathogen incidence (Ball 1983), all off which can result in a very rapid reduction in the numbers of adult bees and in the level of brood rearing in the colony (Ball 1994; Sammatoro *et al* 1998).

During the phoretic stage, the feeding of the mites (0.25µl per day; Moritz 1981) is probably insufficient to influence a healthy bee. Increasingly, it appears that the major effect of phoretic *Varroa destructor* feeding on adult bees is in the transfer and triggering of secondary infections, especially viruses, which are the primary cause of mortality in varroa-infected colonies (Bailey *et al* 1983; Ball & Allen 1988; Allen & Ball 1996; Ball 1997; Fries 1997; Brødsgaard *et al* 2000). Viruses in honeybees are typically benign, rarely being detectable and practically never resulting in colony mortality (Ball & Allen 1988). These viruses have become significant with the spread of varroa mites, with the mite acting as a sort of honeybee HIV, although in this case the mite is both a transmitter and a releaser of the pathogen. Acute Paralysis Virus (APV), in particular, has been associated with colony deaths in Europe (Ball & Allen 1988) and in the USA (Hung *et al* 1996). Other viruses that have been implicated in colony collapses are Deformed Wing Virus (DWV), Slow Paralysis Virus (SPV) and Cloudy Wing Virus (CWV) (Martin *et al* 1998).

The relationship between mite infestation and virus infection seems to be far from being clearly understood. The term "bee parasitic mite syndrome" has been used to describe a disease complex in which colonies are simultaneously infested with mites and infected with viruses and accompanied with high mortality (Shimanuki *et al* 1994). Although the mite has been demonstrated to act as an activator of inapparent virus infections and as a virus-transmitting vector (Ball & Allen 1988; Bowen-Walker *et al*

1999), no direct link between the actual mite population and colony collapse has been found (De Guzman *et al* 1996; Martin 1997b). Furthermore, contradictory results from different studies have caused confusion about the importance and the extent of the damage caused by some honeybee viruses. In contrast with the reports by Bailey and Ball (1991) indicating that the acute bee paralysis virus (ABPV) had never been associated with disease mortality in nature, ABPV was detected in large amounts in dead adult bees and diseased brood from the mite-free countries Belize and Nicaragua (Allen & Ball 1996). In another study, Hung and colleagues (1996) reported that no virus particles have been found in some dead adult bees collected from two colonies with bee parasitic mite syndrome. This has led to suggestions that the mite and the virus are part of a complex multiple-factor problem involved in the collapse of mite-infested colonies (Hung *et al* 1996; Martin 2001).

Other pathogens implicated in the varroa-mediated collapse of honeybee colonies are the tracheal mite (*Acarapis woodi)* and the causative organism of chalkbrood, the fungus *Ascosphaera apis*. Downey & Winston (2001) report a synergistic effect of tracheal and varroa mites in Canada, with colonies infested with both types of mite dying more rapidly than colonies with only varroa mites. Symptoms associated with colonies infested with both types of mite include a reduction in the number of adult bees in the colony, evacuation of the colony by crawling bees, queen supersedure, a spotty brood pattern, and larvae that appear to be diseased (Hung *et al* 1995; Shimanuki & Knox 2000). The report by Çakmak *et al* (2003) that honeybee populations in Turkey have not suffered significant varroa mortality despite substantial varroa populations also suggest a synergism between the two species of mite, as tracheal mites have not yet been found in Turkey. As tracheal mites are present in South Africa (Buys 1995; ARC-PPRI 2001), a contribution to colony collapse might be expected.

The fungal infection chalkbrood is transmitted in honeybee brood food (Shimanuki *et al* 1992), with infected brood becoming encased in mycelial growth and removed from the colony. It has been reported (Liu 1996; Medina & Mejia 1999) that chalkbrood becomes more pronounced in colonies infested with varroa mites. In contrast, neither nosema disease (Bermejo & Fernández 1997) nor American Foulbrood (AFB) (Brødsgaard *et al* 2000) appear to be stimulated by varroa mite infestations.

An additional concern as regards the varroa mite in South Africa is the so-called ‘Capensis Problem’. In 1990, colonies of the Cape honeybee, *Apis mellifera capensis*, were moved out of their native range by beekeepers and introduced into the Limpopo Province of South Africa (Allsopp 1992; Allsopp 1993; Allsopp 2004). They were housed in apiaries with colonies of the local Savanna honeybee, *A. m. scutellata*, and some of the Cape workers invaded Savanna colonies. Cape workers appeared to activate their ovaries and become reproductively active (Allsopp 1993; Martin *et al* 2002; Neumann and Hepburn 2002). Unlike other honeybee subspecies where workers produce males by arrhenotokous parthenogenesis, workers of the Cape honeybee produce female offspring through thelytoky (Onions

1912; Anderson 1963). Hence, the number of Cape workers in the colonies increases, eventually resulting in the death of the Savanna queen (Martin *et al* 2002; Neumann and Hepburn 2002). The Cape workers then took over the reproduction of these colonies, produced large numbers of Cape laying workers, but as these bees are all essentially reproductives, there is little or no foraging in these colonies, and they soon run out of nectar and pollen reserves. These colonies then dwindle in size to only a few hundred bees, which then either die-out or invade other *scutellata* colonies, thus repeating the cycle. Yearly, this 'Capensis problem' causes the loss of thousands of commercial Savanna honeybee colonies (Allsopp 1993; Martin *et al* 2002).

A crucial factor in the "Capensis Problem" is that it results in a breakdown in normal hive activity; it causes bees to "lose morale". This is frequently manifested by colonies becoming less defensive and less hygienic. All normal pathogens, pests and parasites in the colonies become more pronounced (ARC-PPRI 2001), including benign pests such as *Braula*, lesser waxmoth and small hive beetle. As hygienic behaviour is generally believed to be a key factor in determining the response of a honeybee colony to varroa mites (Spivak & Gilliam 1998) it is reasonable to suppose that *Apis mellifera scutellata* colonies afflicted by the Capensis Problem would be especially susceptible to varroa mites (Allsopp 1997b).

The honeybee population need not collapse due to the mite for individual colonies to have suffered negative consequences, or for the population to lose value in South Africa as producers of honey and the pollinators of commercial and indigenous flora. Kralj and Fuchs (2002) showed that mite infestation influences flight behaviour and can both decrease flight duration and increase the loss of workers during foraging. The release of secondary pathogens by the mite might also result in a decrease in colony viability, without the colony actually succumbing to the varroa infestation. Few studies have investigated the impact of varroa mites on the pollination efficacy of honeybees.

With the arrival of varroa mites in South Africa in 1997, and its subsequent spread throughout the honeybee population of the country, it was important to determine what impact the mite was having on the survival and viability of commercial honeybee colonies. Initial surveys indicated very large populations of mites in colonies (Table 2.3; Appendix I) and these surveys were accompanied by reports from beekeepers that colonies were dying in large numbers. These initial reports were investigated by comparing varroacide-treated colonies with non-treated colonies. When it became apparent that wide-scale population collapse was not imminent, a large-scale monitoring project of commercial colonies was instituted. The effect of varroa infestation on the pollination efficacy of commercial colonies was also investigated. Lastly, it was important to determine if varroa mites were acting in concert with other known honeybee parasites and problems in South Africa to cause colony collapse.

MATERIALS & METHODS

Size of varroa population in colonies of *Apis mellifera scutellata* and *Apis mellifera capensis*

The impact of varroa mites on honeybee colonies in South Africa is likely to be determined by the ability of the mites to reproduce in these colonies, and hence the mite population size in the colonies. Using the varroa loads for colonies measured during the various surveys for *Varroa destructor* in South Africa (Chapter 2; Appendix I), a range of mite population sizes in Cape honeybee colonies in South Africa between 1998 and 2000 was estimated, using standard methods. Martin (1998) determined accurate correlation coefficients that allow for the estimation of the varroa population in a honeybee colony from one sample number; this number can be the number of varroa mites found on worker brood, drone brood or adult bees from the colony, or collected on a varroa screen beneath the colony. For the United Kingdom the correction figure for a sample of adult bees collected during summer is as follows (Martin 1998):

$$\frac{\text{Number of bees infected}}{\text{Number of bees sampled}} \times \text{number of bees in colony} \times 2.9 = \text{Estimated number of mites in colony}$$

Other reports suggest using a correction factor of between 2.5 and 3.0 for adult bee samples collected during summer months (Goodwin & van Eaton 2001). During 2001 and 2002 data was collected in South Africa for both *Apis mellifera scutellata* and *A. m. capensis* to determine the appropriate correction figures for varroa sampling in African honeybees (Wilkinson & Allsopp unpublished data). The appropriate correction figure for adult bees during summer months in South Africa was determined to be 3.4, an increase on European figures probably resulting from there being more brood in African honeybee colonies relative to the adult honeybee population.

Direct Mortality Caused by Varroa

Reports from beekeepers in the Kwazulu-Natal (KZN) Midlands in March 1999 indicated that large numbers of colonies were collapsing and dying. These colony collapses, reportedly up to 30% of colonies for some beekeepers, were accompanied by symptoms identical to those predicted by international varroa researchers. Five apiaries belonging to three beekeepers were visited and data collected from a total of 49 colonies. Data collected was as follows: frames of bees and frames of worker and drone brood present, determined by standard procedures (Allsopp & Hepburn 1997); queen presence; and typical varroa symptoms such as dead pupae and malformed bees (Martin *et al* 1998). A sample of approximately 400 worker bees was collected from the brood nest of each colony and screened for varroa mites using the hot-water method (Chapter 2). Twenty-five of the colonies examined were given Bayvarol (Bayer SA) varroacide strips which had already been demonstrated to be 100% efficient in the control of varroa mites under South African conditions (Allsopp unpublished data) whilst the rest of the colonies were left

untreated. All colonies were then left untouched for a period of fourteen weeks at which time they were again thoroughly examined and samples taken, and a comparison made of the treated and untreated colonies.

In addition to the reports of colony collapse in KZN, there were also reports of similar losses in the Western Cape. A large apiary of forty-one colonies belonging to a beekeeper in Paarl was separated into two smaller apiaries approximately two kilometers apart in October 1999. Basic data was collected for all colonies and worker samples were collected and screened with the hot-water method. The colonies in one apiary were treated with Bayvarol strips (Bayer SA) whilst the colonies in the other apiary were left untreated. All colonies were then left untouched for a period of fourteen weeks at which time they were again thoroughly examined and samples taken, and a comparison made of the treated and untreated colonies.

Varroa Monitoring in Commercial Honeybees

In an effort to determine the impact of varroa infestation on the commercial Cape honeybee colonies, commercial beekeepers in the Western Cape were approached in March 1999 and ask to participate in a monitoring programme. A total of 20 beekeepers volunteered to participate, and offered a total of 473 colonies for the programme. All the beekeepers participated in a training course during which they were shown what data to collect from colonies and how to collect worker bee samples for varroa analysis. The beekeepers were also provided with a datasheet requiring the following information for each colony, again using standard procedures (Allsopp & Hepburn 1997).

- Beekeepers name & date when data was collected
- Place were colonies are located and colony number
- Recent history (< 3 months) of the colony, specifically if it had been used for pollination or moved to honey flow
- If the colony was empty or dead, any indication of the cause (pesticides, honey-badger, theft)
- The amount of worker brood, and the amount of drone brood, in frames
- The amount of stored pollen, in frames
- The size of the colony in frames of bees with “10” representing a full brood box, “15” a brood box with full super, “20” a brood box with two full supers, and so forth
- The presence of the queen, as indicated by open brood, or the presence of queen cells
- The number of honey frames (brood frames or equivalent) removed from the colony

The beekeepers were asked to dedicate an apiary each (approximately 20 colonies) to the monitoring programme. Colonies in this apiary were not to be given any varroacide treatment, and were not to be placed in the vicinity of any other colonies that might have received varroacide treatment. Otherwise, the

colonies were to be treated as normal commercial colonies, and were to be used for commercial pollination and honey production as required. The participating beekeepers were required to inspect and sample their colonies every 3-4 months, and deposit the completed datasheet, together with a honey bottle with approximately 400 worker bees collected from the brood box of each colony for varroa screening, at ARC-PPRI. Each of these samples was then processed for varroa mites using the hot-water method. It was expected that the monitoring programme would continue for a period of three years, following which time an assessment would be made of the impact of the mite on the commercial honeybee population of the Cape.

Effect on Pollination Efficiency

To assess the impact that heavy varroa-infestations have on commercial honeybee pollination, an apiary belonging to a commercial beekeeper whose colonies were known to have heavy varroa infestation, was selected in October 1999. All colonies in the apiary had a common history. 24 colonies of roughly equivalent strength were selected and randomly divided into two groups of 12 colonies each. These two groups were moved to new apiaries, separated by a distance of approximately one kilometer. All colonies were sampled for varroa mites, using the hot-water method (Chapter 2), to confirm the heavy varroa infestation. Numbers of varroa mites per 100 worker bees in the colonies were 15.46 ± 6.42 in the one group of colonies and 14.85 ± 5.12 in the other group, varroa loads indicating more than 10 000 mites per colony and a level of infestation that would be regarded as being deleterious to the viability of the colonies. The 12 colonies in one group were given varroacide strips (Bayer SA; 4 strips per colony) while the other colonies were left untreated. The colonies were then left alone until they were needed for the pollination of pumpkins in early February 2000. The colonies were assessed and basic data collected (Allsopp & Hepburn 1997), samples collected for varroa screening, and the colonies moved into the pumpkin fields as illustrated in Figure 3.1. Two very large pumpkin fields were used for the experiment, and 6 treated and 6 untreated colonies were introduced on opposite sides of each field. The groups of colonies were 300 metres apart. The foraging rates of the colonies were assessed for a period of three days to determine peak foraging period. Thereafter, the foraging rate of each colony (determined by the number of departing foragers in two minutes) was monitored at this peak foraging time each day for seven days. The entrance of each colony was also briefly closed each day and a total of 20 returning pollen foragers collected for each colony. The pollen on these foragers was identified as either pumpkin pollen or “other” pollen. In addition, a total of 200 female flowers, all of which opened during the same seven days that the colonies were in the fields, were tagged (100 flowers for each field), these flowers being within 25 metres of a group of colonies. The percentage of these tagged flowers that yielded mature pumpkins was determined after six weeks.

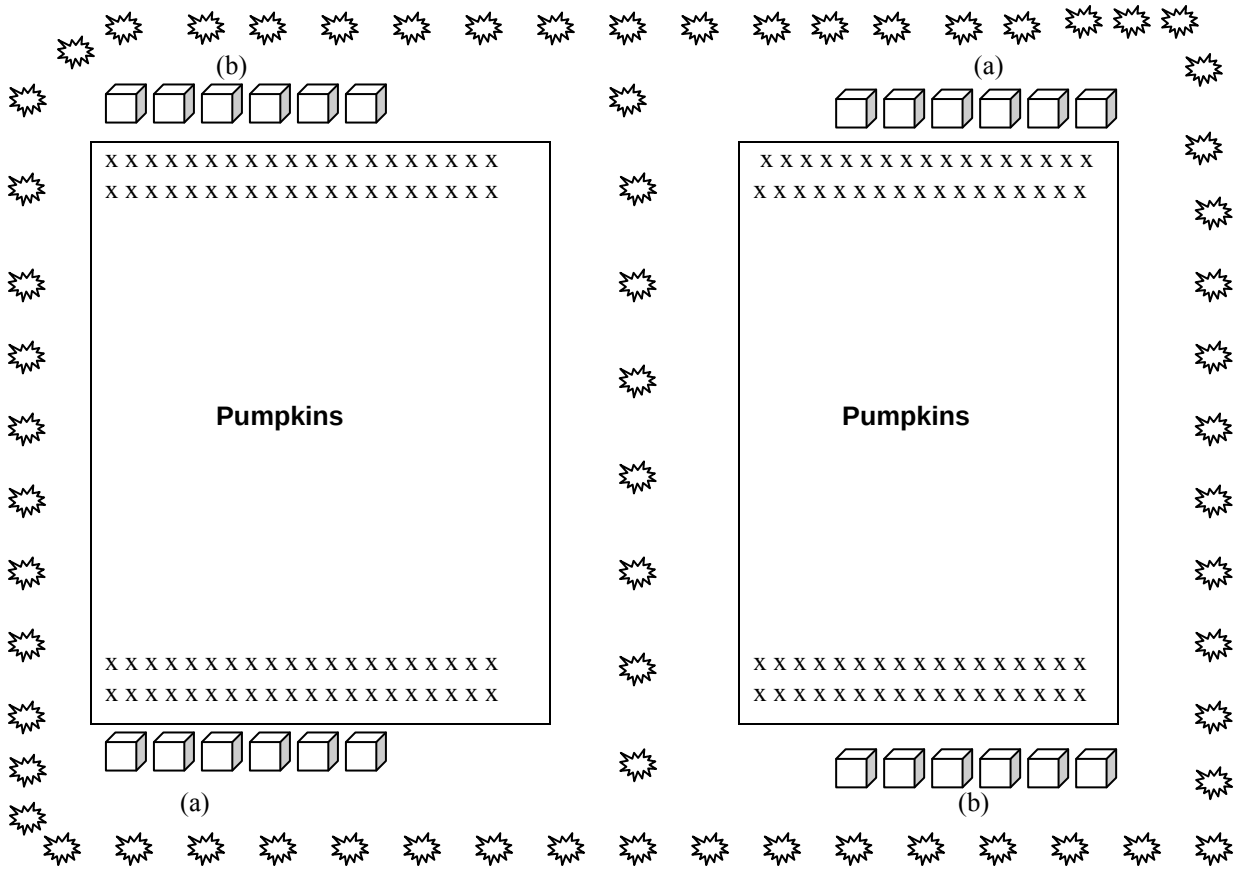


Figure 3.1: Evaluation of pollination efficacy of pumpkins of varroacide treated (a) and untreated colonies (b). Twelve varroacide treated colonies and twelve untreated colonies ( ) are placed around two large pumpkin fields, separated by pine trees ( ). The foraging rates of all colonies are recorded daily for two minutes, for a period of seven days. The fruit set of 100 marked pumpkin flowers (x), situated immediately adjacent to each of the treated and untreated colonies, was monitored. The percentage of pumpkin pollen foragers returning to each colony was also determined.

A second pollination trial was carried out on apples in October 2000, and was similar to the pumpkin trial in most respects. Once again honeybee colonies belonging to a commercial beekeeper were used, although on this occasion colonies suspected to be relatively lightly infested were chosen. All colonies in the apiary had a common history and in August 2000 12 colonies of roughly equivalent strength were selected and randomly divided into two groups of 6 colonies each. These two groups were moved to new apiaries, separated by a distance of approximately one kilometer. All colonies were sampled for varroa mites, using the hot-water method (Chapter 2), to confirm the light varroa infestation. Numbers of varroa mites per 100 worker bees in the colonies were 3.75 ± 1.54 in the one group of colonies and 4.40 ± 2.04 in the other group, varroa loads indicating approximately 2 000 – 3 000 mites per colony, and a level of infestation unlikely to be deleterious to the viability of the colonies. The 6 colonies in one group were given varroacide strips (Bayer SA; 4 strips per colony) while the other colonies were left untreated. The colonies were then left alone until they were needed for the pollination of Golden Delicious apples in early October.

When the apples were at approximately 10% blossom, the colonies were assessed and basic data collected (Allsopp & Hepburn 1997), samples collected for varroa screening, and the colonies then moved into the orchard as illustrated in Figure 3.2. A large 4.8 hectare orchard was used, with two rows of Golden Delicious trees interspersed with two rows of Braeburn as cross pollinisers. Rows of trees were lengthy with 100-105 trees being planted in each row. The treatment and non-treatment honeybee colonies were introduced in the same pattern as with the pumpkin trial (see Figure 3.2). The foraging rate of each colony (determined by the number of departing foragers in two minutes) was monitored at 09h00 for six days. In addition, a total of 480 clusters of apple blossom were counted and tagged. Twenty of these clusters were in the first ten trees of the Golden's rows adjacent to each colony of bees (Near To Bees) and twenty of these clusters were in trees 31-40 of the same rows of trees (Far From Bees; Figure 3.2). The number of fruit set in each of these clusters was checked after eight weeks and the fruit set percentage determined.

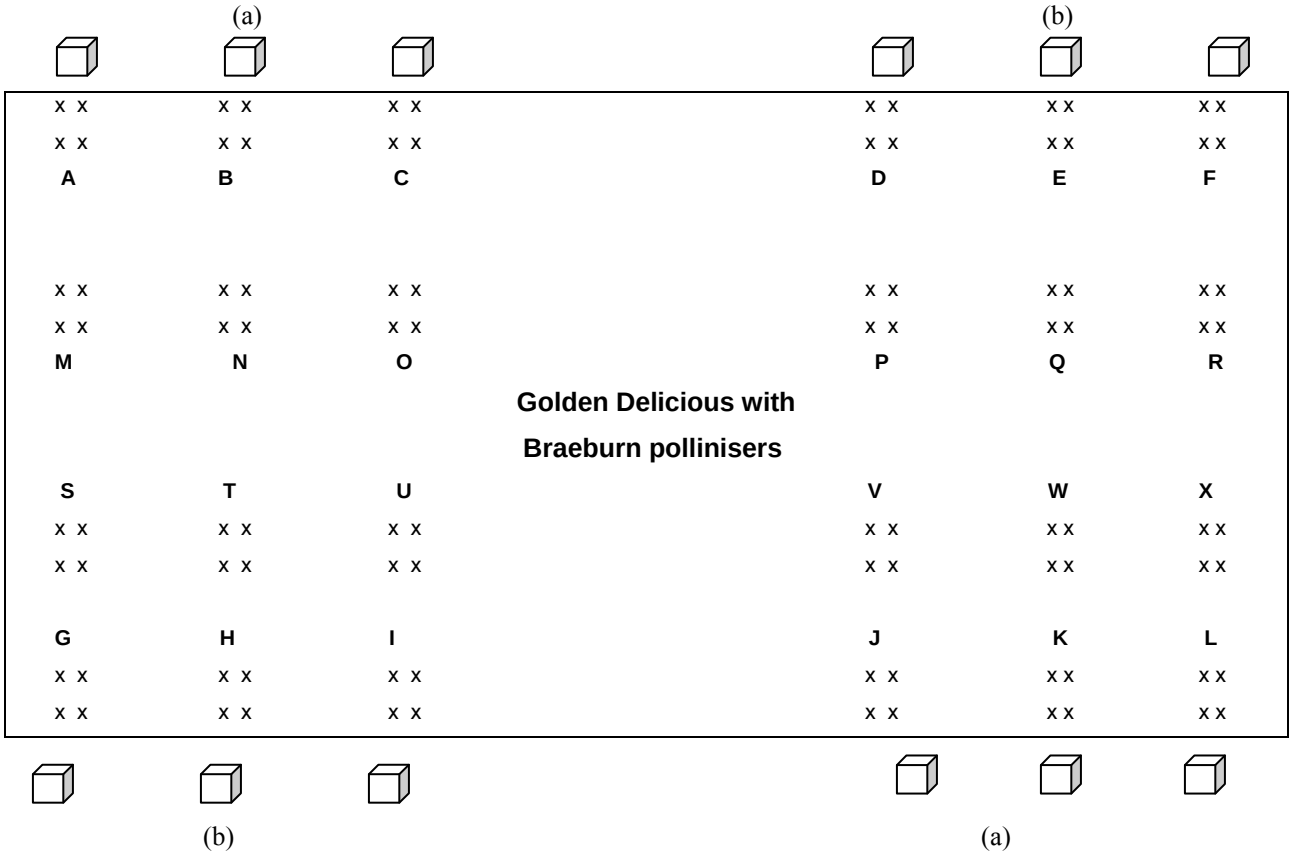


Figure 3.2: Evaluation of pollination efficacy of apples of varroacide treated (a) and untreated colonies (b). Six varroacide treated colonies and six untreated colonies ( ) are placed around a large Golden Delicious orchard. The foraging rates of all colonies are recorded daily for two minutes, for a period of six days. The fruit set of 480 marked apple blossom clusters was monitored. Twenty of the clusters were placed in Golden Delicious trees immediately adjacent to each of the introduced colonies (within ten trees; A to L; x represents 20 clusters) and twenty more of the clusters in the same rows of trees but 31-40 trees away from the colonies (M to X; x represents 20 clusters). The fruit set percentage of these clusters was then determined.

Secondary Diseases & Pests

1. Tracheal Mites

Acarapis woodi, the honeybee tracheal mite, was first detected in South Africa in an ARC-PPRI apiary in Stellenbosch in 1995 (Buys 1995). Samples from this apiary as well as five other apiaries in the vicinity were sampled for both tracheal mites and varroa mites in May and September 1999, and May and September 2000. A total of 96 colonies were sampled in May 1999, with the colonies being individually marked. All remaining colonies were sampled during the subsequent sampling periods. On each occasion a worker sample was collected from the brood nest of each colony and the varroa load determined by the hot water method (Chapter 2). A sample of older bees from honey supers or honey frames was collected for tracheal mite analysis (Shimanuki & Knox 2000) and preserved in 70% ethyl alcohol. Twenty bees per colony were dissected by pinning the bee on its back and removing the head and first pair of legs with a scalpel. The first ring of the thorax was then removed with forceps under a dissecting microscope and the exposed trachea removed to a drop of 85% lactic acid on a glass slide (Shimanuki & Knox 2000). A cover slip was placed on the slide which was examined at 40X on a compound microscope. The number of bees with tracheal mites and the number of tracheal mites was counted.

2. Capensis Problem

Twenty colonies belonging to a Gauteng beekeeper, all recently caught swarms from Piet Retief and housed in an apiary near Heidelburg (Gauteng), were monitored for varroa mites and the level of Cape honeybee infestation (Allsopp 1993). The colonies were monitored every two months from May 1999 until January 2000 when the experiment was terminated as too few colonies remained alive. All colonies were queenright and without obvious Cape laying worker activity at the beginning of the monitoring period and all were housed in normal 10-frame Langstroth boxes without supers. The colonies were not moved for the duration of the monitoring period. On each occasion that the colonies were monitored, the number of frames of bees and amount of brood was recorded, following standard procedures (Allsopp & Hepburn 1997). A worker sample of approximately 400 bees was collected for varroa screening using the hot-water method (Chapter 2). A random sample of 20 bees was also collected from each colony and the ovaries of these bees dissected out. Bees with a combined ovariole count of more than 16 were designated as *A.m.capensis* (Hepburn & Crewe 1990). The percentage of the workers with mature ovaries (with eggs) was also determined for each sample. Comparisons were made between the *capensis*-state of the colonies, the varroa load in the colonies, and the vitality of the colonies.

Statistical Analysis

Data were analysed using the programme Statistical Analysis System (SAS), version 8.2, 1999. Each variable was tested using either a parametric or non-parametric test depending upon whether the data was continuous data (like weight) or ordinal data (classes). A one–way analysis of variance (ANOVA) was the parametric test used to test whether the difference between groups was significantly different ($p \leq 0.05$). A normal distribution of the residuals is an assumption of ANOVA and was tested by the Shapiro Wilk non-normality test (Shapiro and Wilk 1965). If the percentage data was not normally distributed, a logit transformation was performed (Snedecor & Cochran 1967). The Student's t-Least Significant Difference was calculated at the 5% confidence level to compare the effect of varroacide treatment with control colonies as regards the effect on colony strength, brood production, foraging rates, pollen collection, varroa load and effect on fruit set in apple pollination. Pearson's Product Moment Correlation Coefficients ($p \leq 0.05$) was used to test the relationship between variables (correlations).

As regards the non-parametric data, a standard Chi-squared test ($p \leq 0.05$) was carried out on the direct mortality data, to assess the effect of varroa mites on the survival of colonies in the Western Cape and in Kwazulu-Natal, and on fruit set in the pumpkin pollination experiment. The varroa monitoring data was ordinal in nature, therefore a Kruskal-Wallis test was performed ($p \leq 0.05$). These data were also ranked to investigate the effect of varroa mites on colony mortality, and Tukey's Studentized Range (HSD) Test was used in comparing the treatment means ($p \leq 0.05$).

RESULTS

Size of varroa population in colonies of *Apis mellifera scutellata* and *Apis mellifera capensis*

The *Varroa destructor* population in colonies of *A.m.capensis* and *A.m.scutellata* were estimated using data collected during varroa surveys of 1998 and 1999 (Appendix 1). Data from three commercial apiaries were selected, these sites being Joostenbergvlakte (4/11/98), Richmond, KZN (11/98) and Heidelburg, Gauteng (20/04/99). These apiaries comprised Cape honeybees and two regions of Savanna honeybees, and were selected as they represented the peak mite infestation levels found during the varroa surveys. A range of mite population sizes in these colonies was estimated using standard methods (Martin 1998). The correction figure for a sample of adult bees collected during summer in the United Kingdom was used (Martin 1998) as well as the appropriate correction figures for varroa sampling in African honeybees (Wilkinson & Allsopp unpublished data). Average number of bees in a colony was conservatively estimated at 20 000 bees, representing approximately eight frames of bees (Martin 1998; Wilkinson & Allsopp unpublished data). Using these methods the average number of varroa mites found in colonies of honeybee in South Africa during peak infestation was estimated to be between 10 000 and 17 000 mites, with the most heavily infested colonies having between 33 000 and 50 000 mites (Table 3.1).

Table 3.1: Estimation of varroa mite population levels in South African honeybee colonies.

Apiary	Honeybee race	Varroa mites per 100 bees		Estimated number of bees in colony	Estimated mite population size using the UK correction figure (2.9)		Estimated mite population size using the SA correction figure (3.4)	
		Average	Maximum		Average	Maximum	Average	Maximum
Joostenberg-Vlakte (37 colonies)	*A m capensis*	17.4	65.0	20 000	10 092	37 700	11 832	44 200
Richmond (KZN) (38 colonies)	*A m scutellata*	25.1	58.0	20 000	14 558	33 640	17 068	39 440
Heidelburg (Gauteng) (80 colonies)	*A m scutellata*	20.7	72.7	20 000	12 006	42 166	14 076	49 436

Direct Mortality Caused by Varroa

The inspection of colonies reported in 1999 by beekeepers in both Kwazulu-Natal (KZN) and the Western Cape to be collapsing from varroa mites revealed symptoms identical to those reported for varroa-mediated colony collapse in other parts of the world (Bailey & Ball 1991; Martin *et al* 1998). The results of these inspections are presented in Appendix II, and can be summarized as follows:

- Colonies often had large amounts of brood, but with very few bees, certainly too few bees to produce that amount of brood.
- Colonies with masses of stored honey, but again with very few bees present.
- Large numbers of dead pupae, and in some cases, dead adult bees, at the colony entrance.
- Large numbers of dead pink-eyed pupae in the cells, these cells having been uncapped. On removal these pupae appear totally normal. In extreme cases, there may be thousands of these dead pupae in a colony. The younger brood (larvae) is all healthy, and most colonies have good numbers of eggs, indicating that the queen is still performing normally.
- In some cases there are dead adult bees in their cells. On removal, varroa are found on most of these bees. These dead bees in the cells are normally disfigured, with vestigial wings and compacted abdomens.
- As a result of the large amounts of dead pupae and dead adult bees, both of which are removed by the workers, the brood pattern becomes extremely patchy
- There are numerous malformed live bees, again with vestigial wings and reduced abdomens.
- Varroa are extremely obvious and visible on the bees in the colony.
- Very obvious chalkbrood in most colonies, with thousands of chalkbrood mummies on the floorboard of the some colonies.

The inspection of the colonies in KZN in March 1999 revealed that most colonies were in an extremely serious condition (Appendix II; Tables 1-5). In some cases as much as 50% of the sealed brood was dead, there were masses of dead pupae at the colony entrance, hundreds of malformed bees in the colonies, and varroa was very visible on the bees. Most of these colonies were extremely weak, with most colonies having varroa loads of more than 10 varroa per 100 bees. It was concluded that the beekeepers were correct in their diagnosis, and that varroa-mediated colony mortality was occurring in these apiaries. A similar situation was later found for the colonies in the Western Cape (Appendix II; Tables 11-12).

The effect of treatment of approximately 50% of these colonies with Bayvarol strips (Bayer SA) is presented in Table 3.2. The data was assumed to be normally distributed (Shapiro-Wilk = 0.975771, $p = 0.6191$). As the comparison was between a treatment group and a control group, the result of the ANOVA ($p \leq 0.05$) is enough evidence to determine whether varroacide treatment of colonies affects colony strength, brood production or varroa loads. A standardized Chi-squared test (2×2, $p \leq 0.05$) was carried out on the survival of colonies in Western Cape and Kwazulu-Natal. In KZN there was no statistically significant difference in colony strength, brood production, varroa numbers or colony mortality between the treatment and control colonies (Table 3.2). In comparison, all variables except colony mortality were statistically significantly different in the Western Cape colonies. Combining the colonies of the two regions, only varroa numbers were statistically different between treatment and non-treatment colonies (Table 3.2).

The data were, however, complicated by the observation that honeybees transmit varroacide treatment throughout an apiary, including to non-treatment colonies in that apiary. In three apiaries in KZN (Appendix II; Tables 1, 2, 5) colonies in the same apiary were randomly selected for treatment or as controls. These colonies were generally spaced within 5 metres of each other. In can be seen that in all three apiaries there was a dramatic increase in the strength of colonies and the amount of brood present, and a drastic reduction in the number of disfigured bees or visible varroa. In addition, the numbers of varroa in these colonies was drastically reduced, with zero varroa being found in most treated colonies, and few varroa being found in the untreated colonies (Appendix II; Tables 6, 7, 10). This significant improvement in the untreated colonies as well as the Bayvarol-treated colonies raised the possibility that it was the onset of the major honey flow that was responsible for the improvement, in addition to the chemical treatment. Analysis of the results from the two apiaries where one apiary was selected for treatment and the other as a control (Appendix II; Tables 3, 4, 8, 9) indicate the importance of colony drift and separate apiary sites in this experiment. In these apiaries the varroa load in all the treated colonies was reduced to zero, and all but one of the untreated colonies had died. Similar results were found in the evaluation of the efficacy of Bayvarol in Stellenbosch (Allsopp unpublished results), indicating that even the presence in a treated apiary is sufficient for non-treated colonies to survive. This indicates that a very significant amount of chemical must be transmitted between colonies in apiary. Colonies removed from treatment apiaries, however, died in the fourteen-week period after treatment.

Table 3. 2: Influence of varroa mites on colony survival and strength in Kwazulu-Natal and the Western Cape. Approximately 50% of colonies in each province were treated with Bayvarol and 50% were left untreated. All colonies were re-examined after fourteen weeks. The average differences in colony strength (frames of bees and frames of brood) and varroa load in surviving colonies per region was determined, as well as for both regions combined. Significant differences between treatment and control colonies (one-way ANOVA, $p \leq 0.05$) are indicated with an asterisk. The survival of treatment and control colonies in the two regions and overall is compared using a standard 2x2 chi-squared ($p \leq 0.05$) with significant differences indicated with an asterisk.

Province	Date of data collection	Treatment		Frames of bees	Frames of brood	Varroa load (mites per 100 bees)	Colonies alive
Kwazulu-Natal	March 1999 (treatment)	Treated		5.76	4.20	7.73	25
		Control		6.23	4.20	7.65	24
	June 1999 (post treatment)	Treated		10.20	4.80	0.02	25
		Control		8.03	4.57	1.04	16
	Differences between control and treatment colonies	Mean	Treated	4.44	0.60	-7.70	
			Control	3.13	0.69	-8.33	
		Standard error	Treated	1.148	0.678	1.590	
			Control	1.153	0.526	1.603	
		Statistic		F=0.59	F=0.01	F=0.07	X^2=0.896
		Probability		P=0.446	P=0.925	P=0.793	P=0.34
Western Cape	Oct 1999 (treatment)	Treated		8.11	2.91	7.76	19
		Control		8.23	2.66	7.37	22
	Jan 2000 (post treatment)	Treated		9.63	5.07	0.18	19
		Control		9.06	3.16	14.51	16
	Differences between control and treatment colonies	Mean	Treated	1.53	2.16	-7.58	
			Control	0.25	0.06	7.72	
		Standard error	Treated	0.504	0.420	1.170	
			Control	0.266	0.3-5	2.147	
		Statistic		F=4.50	F=15.24	F=42.63	X^2=0.477
		Probability		P=0.043*	P=0.0004*	P=0.0001*	P=04899
KZN & Western Cape	Differences between control and treatment colonies	Mean	Treated	3.182	1.273	-7.652	
			Control	1.688	0.367	-0.306	
		Standard error	Treated	0.715	0.438	1.024	
			Control	0.637	0.300	1.984	
		Statistic		F=2.23	F=2.44	F=12.82	X^2=0.896
		Probability		P=0.139	P=0.122	P=0.0006*	P=0.2467

With the benefit of hindsight, this mistake was not made when testing for the effect of varroacide treatment on colonies in the Western Cape (Appendix II; Tables 11-14). Treatment apiaries were separated from control apiaries, and significant differences were found in brood levels, colony strength, varroa loads and colony survival. On the basis of the Western Cape results and the single apiary in KZN where treatment colonies were separated from control colonies (Appendix II; Tables 3, 4, 8, 9), and the non-significant statistical results notwithstanding, it could be safely concluded that colonies in both Kwazulu-Natal and the Western Cape were succumbing to the varroa mite.

Varroa Monitoring in Commercial Honeybees

The complete data from the 473 commercial colonies monitored for varroa mites is presented in Appendix III. Beekeepers were expected to monitor the colonies without treatment for a period of approximately three years, collecting data and samples every 3-4 months. Rapidly weakening colonies and colony losses, however, resulted in all participating beekeepers withdrawing from the programme within 21 months (October 2000), at which stage the monitoring was terminated. A large number of the participating beekeepers had pulled out earlier, after only 12 months, again citing colony losses as the reason. In addition, many of the beekeepers failed to meet the sequential sampling requirements, with 5 beekeepers providing only one sample; and 2 beekeepers providing only 2 samples. On the positive side, a number of beekeepers monitored more than the 20 colonies requested of them, and met their sampling commitments. Datasheets were accurately completed for the most part, and samples for varroa screening correctly collected.

Whilst not as extensive (in duration) as originally planned, the monitoring of 473 colonies represents an extensive data base, and provides valuable information on the impact of varroa mites on the commercial honeybee population of the Western Cape. The average monthly values for frames of bees, worker brood, drone brood and stored pollen, and the average varroa loads per 100 bees, for each of the 21 months of the monitoring period, are indicated in Table 3.3. The varroa loads of all surviving colonies over the entire monitoring period is indicated in Figure 3.3. The data indicates tremendous variability in varroa numbers over the monitoring period, with peaks in the summer months and troughs in the winter months. Except for the last two months of sampling, when relatively few colonies were sampled, there was a gradual increase in varroa numbers across the sampled population over the entire monitoring period.

Table 3.4 and Figure 3.4 show the same data plotted against the time (months) that had passed since the initial inspection of a colony, in effort to monitor the presumed decline in colonies resulting from varroa infestations, and in an effort to counter the colonies being monitored during different months of the year. Once again there was a tremendous variability in varroa loads, with no pattern emerging. This is surprising as it would be expected that varroa concentrations in colonies would gradually increase over time.

Analysis of the data according to season (months of the year; Table 3.5; Figures 3.5 & 3.6) confirms that varroa numbers in colonies are greatest in early summer and lowest in late winter. Varroa loads (mites per 100 worker bees) are surprisingly low in late summer (January – February), probably due mostly to the rapid increase in the honeybee populations in colonies at this time of the year. Hence, this "decrease" in varroa numbers in late summer is essentially a result of the sampling procedure, and does not reflect a real decrease in varroa numbers in the colonies. Conversely, varroa loads were extremely high soon after winter, when the colonies are still relatively small. It can also be seen that the seasonal increase in varroa numbers corresponded well with peak drone brood production in August, with varroa numbers increasing from September (Figure 3.6). Finally, the decrease in worker brood production after February indicated the critically vulnerable period for colonies with respect to the varroa mite, a period when large numbers of mite are present but limited amounts of brood, and when entire cohorts of immature bees may be damaged by mite parasitism, precipitating colony collapse.

The data were tested for analysis of variance testing the relationship between colony parameters and the varroa loads of the colonies, using Pearson's Product Moment Correlation Coefficients ($p \leq 0.05$). The relationships between colony size in frames of bees, amount of worker brood, amount of drone brood, amount of stored pollen, time after the onset of monitoring and varroa load (mites per 100 bees) in the Cape commercial honeybee population is indicated in Table 3.6, with statistically significant correlations indicated with an asterisk. Varroa numbers in the Cape commercial population are found to be statistically and negatively correlated with the amount of bees in the colonies, with the amount of worker brood, with the amount of drone brood, and with the amount of stored pollen. Clearly, an increase in varroa mites in a colony corresponded with a decrease in all parameters representing colony vitality. In addition, varroa numbers in the population were significantly and positively correlated with time after the onset of the monitoring, indicating an increase in varroa mites in the honeybee population. Not surprisingly, the size of the colony was positively and significantly correlated with the amount of worker brood, the amount of drone brood and the amount of stored pollen, and brood levels and pollen storage were also significantly and positively correlated. It would be fair to conclude that any one of these parameters (colony size, worker brood levels, drone brood levels, or amount of stored pollen) could be used to monitor honeybee colony vitality, certainly with respect to the impact of varroa mites. The conclusion that varroa mites were negatively affecting honeybee colonies in the Cape was supported by the significant and negative correlations between colony size, the amount of worker brood, and the amount of stored pollen, respectively, and time after the onset of monitoring. On the evidence of this monitoring programme, it was clear that the varroa mite infestation of commercial *Apis mellifera capensis* colonies during the years of 1999 and 2000 was damaging to the bees and that the damage was increasing over time.

Table 3.3: Varroa monitoring in 473 commercial Cape honeybee colonies, between January 1999 and October 2000. The average for each sampling month is followed by the number of colonies inspected during that month (n).

Date of Sample	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Varroa mites per 100 bees
January 1999		3.68942	0.03583	1.19583	2.51000
	0	52	60	60	60
February 1999	13.5000	1.50096	0.17788	0.25692	2.51154
	26	26	26	26	26
March 1999	11.4500	3.53550	0.30400	2.49850	1.14000
	20	20	20	20	20
April 1999	8.4078	1.73906	0.09890	1.23453	4.70611
	166	170	170	170	167
May 1999	9.3592	1.87964	0.02558	1.09913	6.55646
	238	239	240	240	240
June 1999	9.9715	3.12344	0.20313	0.79313	3.50188
	79	80	80	80	80
July 1999	8.9111	2.87361	0.13542	0.53090	2.97659
	90	90	90	89	88
August 1999	7.4500	3.46238	0.18713	1.80305	4.08500
	20	20	20	20	20
September 1999	8.5033	4.15811	0.34045	0.91438	3.39081
	153	153	153	152	149
October 1999	10.9833	2.74353	0.15000	0.76042	8.18655
	30	29	30	30	29
November 1999	6.5000	2.48558	0.05288	1.55048	8.70870
	26	26	26	26	23
December 1999	9.6403	3.91814	0.19859	1.50507	8.27071
	98	102	102	102	99
January 2000	8.2015	2.03337	0.06740	0.60437	4.24394
	103	103	102	103	99
February 2000	14.0349	2.76163	0.02616	1.07558	4.83279
	43	43	43	43	43
March 2000	5.4207	1.21059	0.01441	0.54583	6.61209
	82	85	85	84	86
April 2000	9.5625	3.14578	0.13359	1.48438	5..6438
	16	16	16	16	16
May 2000	6.2000	0.78792	0.03362	0.41267	6.42375
	30	30	29	30	36
June 2000	5.7500	1.02778	0.00647	0.42835	7.37111
	40	45	45	41	45
July 2000	3.6887	0.76157	0.00648	0.15833	7.60712
	53	54	54	54	52
September 2000	6.1579	2.41250	0.05625	0.29605	4.05350
	19	20	20	19	20
October 2000	11.5455	6.36364	0.30556	1.81818	0.57182
	11	11	9	11	11

Table 3.4: Varroa monitoring in 473 commercial Cape honeybee colonies between January 1999 and October 2000, recorded as months since the first samples were taken from each colony. The average for each sampling period is followed by the number of colonies inspected of that given time period (n).

Months since first inspection	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Varroa mites per 100 bees
0	10.2583	2.43893	0.11852	1.23257	4.28843
	384	438	447	446	447
1					
2	8.0250	2.91650	0.05225	1.13967	3.21326
	90	90	90	90	89
3	8.0265	1.55390	0.06017	0.38454	6.67346
	132	134	134	134	130
4	8.3284	4.21920	0.21649	0.79276	4.39420
	67	69	69	69	69
5	7.8077	3.49769	0.16814	1.33932	3.24135
	39	39	39	38	37
6	8.6087	2.25972	0.04620	1.05707	8.50465
	46	45	46	46	43
7	9.5536	4.06696	0.56101	1.66518	5.42564
	42	42	42	42	39
8	10.4384	3.36841	0.12699	0.88688	4.24733
	138	138	138	138	135
9	7.9789	2.34355	0.17881	0.92874	5.92479
	94	95	95	95	94
10	7.2167	1.90000	0.055833	0.90000	4.59643
	15	15	15	15	14
11	8.0541	2.75128	0.08466	1.04231	8.24116
	74	78	77	78	82
12					
13	6.2746	1.32944	0.04618	0.62767	7.13000
	71	72	71	72	72
14	5.7264	1.19492	0.01017	0.47037	4.77067
	53	59	59	54	60
15	802333	1.31667	0.00833	0.56667	5.55667
	15	15	15	15	15
16	4.3864	1.67391	0.04348	0.20652	7.80609
	22	23	23	23	23
17	9.7500	4.77083	0.19531	1.33088	1.65667
	18	18	16	17	18
18	3.8953	0.79545	.0.00227	0.15455	6.51357
	43	44	44	44	42

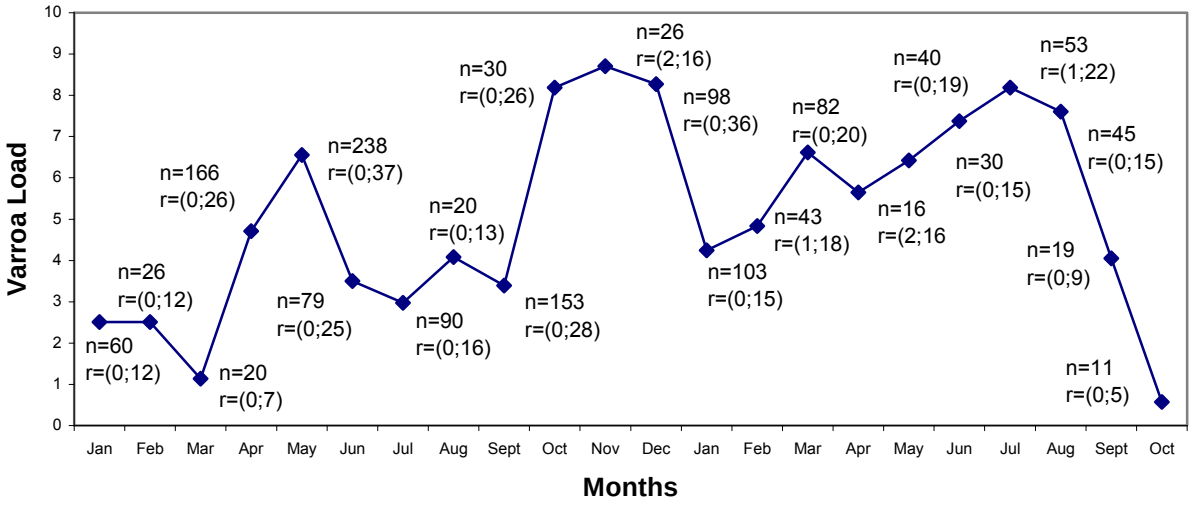


Figure 3.3: Varroa monitoring in 473 commercial Cape honeybee colonies between January 1999 and October 2000, indicating the average numbers of mites in colonies for each month of the monitoring period. The number of colonies sampled each month is indicated (n) as is the range of varroa load (mites per 100 bees) recorded (r).

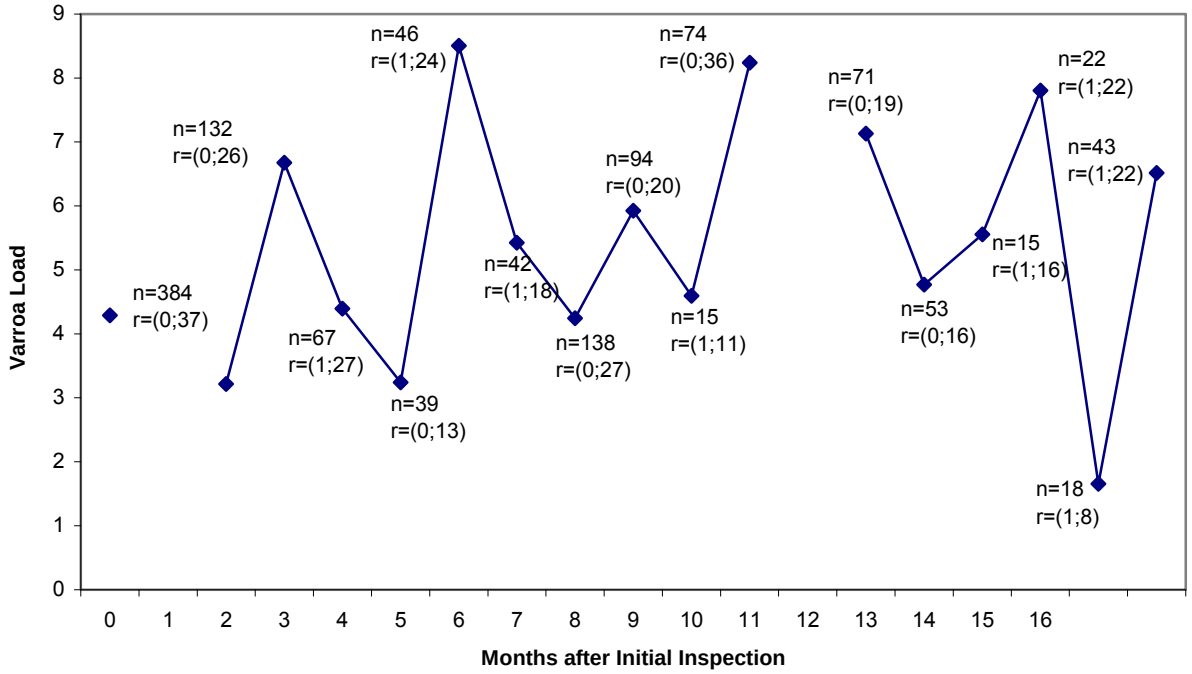


Figure 3.4: Varroa monitoring in 473 commercial Cape honeybee colonies between January 1999 and October 2000, indicating the average numbers of mites in colonies with respect to the number of months since the initial inspection was made. The number of colonies sampled each month is indicated (n) as is the range of varroa load (mites per 100 bees) recorded (r).

Table 3.5: Varroa monitoring in 473 commercial Cape honeybee colonies between January 1999 and October 2000. The average for each month of the year is followed by the number of colonies inspected during that month (n).

Month	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Varroa mites per 100 bees
January	8.2015	2.58895	0.05571	0.82209*	3.58962
	103	155	162	163	159
February	13.8333	2.28659	0.08333	0.76710	3.95812
	69	69	69	69	69
March	6.6029	1.65343	0.06957	0.92135	5.57962
	102	105	105	104	106
April	8.5093	1.86007	0.10188	1.25602	4.73743
	182	186	186	186	183
May	9.0056	1.75789	0.02645	1.02286	6.53915
	268	269	269	270	276
June	8.5525	2.36900	0.13233	0.66952	4.89480
	119	125	125	121	125
July	6.9755	2.08160	0.08707	0.39021	4.69650
	143	144	144	143	140
August	7.4500	3.46238	0.18713	1.80305	4.08500
	20	20	20	20	20
September	8.2442	3.95630	0.30760	0.84568	3.46923
	172	173	173	171	169
October	11.1341	3.73906	0.18590	1.04421	6.09250
	41	40	39	41	40
November	6.5000	2.48558	0.05288	1.55048	8.70870
	26	26	26	26	23
December	9.6403	3.91814	0.19859	1.50507	8.27071
	98	102	102	102	99

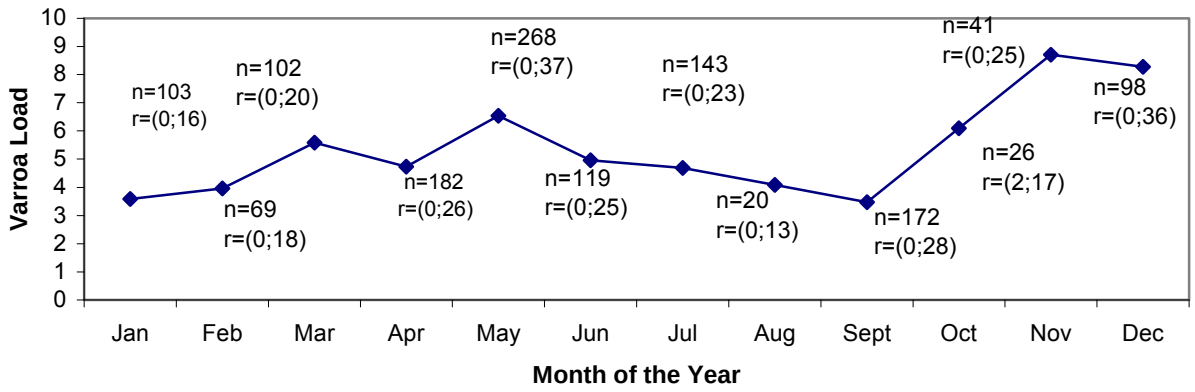


Figure 3.5: Varroa monitoring in 473 commercial Cape honeybee colonies between January 1999 and October 2000, indicating the average numbers of mites in colonies with respect to each month of the year. The number of colonies sampled each month is indicated (n) as is the range of varroa load (mites per 100 bees) recorded (r).

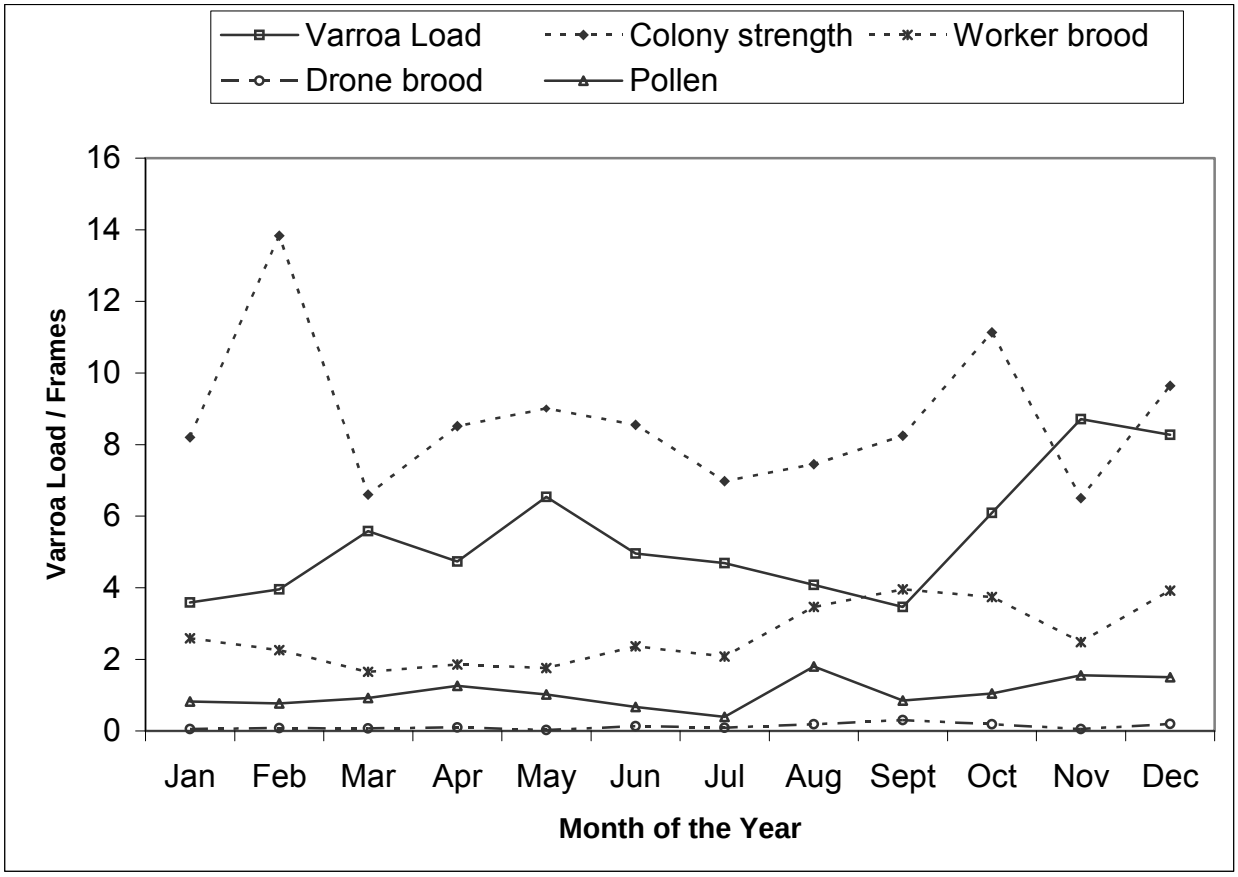


Figure 3.6: Varroa monitoring in 473 commercial Cape honeybee colonies between January 1999 and October 2000, indicating the average frames of worker bees, frames of worker brood, frames of drone brood, frames of stored pollen, and numbers of varroa mites per 100 worker bees in colonies with respect to each month of the year.

Table 3.6: Pearson's Product Moment Correlation Coefficients, $p \leq 0.05$ was used to test the relationship between colony size, amount of worker brood, amount of drone brood, amount of stored pollen, time after the onset of monitoring and varroa load (mites per 100 bees) in the commercial honeybee population. Statistically significant correlations are indicated with an asterisk.

	Size	Worker	Drones	Pollen	Time
V/Load	r=-0.12731*	r=-0.26355*	r=-0.12472*	r=-0.10840*	r=0.12919*
	p=0.0001	p=0.0001	p=0.0001	p=0.0001	p=0.0001
	n=1322	n=1392	n=1398	n=1395	n=1409
Size		r=0.42225*	r=0.16058*	r=0.26282*	r=-0.31804*
		p=0.0001	p=0.0001	p=0.0001	p=0.0001
		n=1341	n=1339	n=1340	n=1343
Worker			r=0.30958*	r=0.23817*	r=-0.11513*
			p=0.0001	p=0.0001	p=0.0001
			n=1410	n=1406	n=1414
Drones				r=0.24050*	r=-0.04713
				p=0.0001	p=0.0758
				n=1412	n=1420
Pollen					r=-0.17696*
					p=0.0001
					n=1416

The same data was tested for a survivability interaction; that is, a correlation between colonies that had died during the monitoring period (Appendix III) and the varroa loads in these colonies in the sampling period before their demise, in comparison with colonies from the same sampling period (month) that were alive in the subsequent inspection. The Kruskal-Wallis ($p \leq 0.05$) test for non-parametric data was used and no significant differences were found in varroa numbers between "colonies dead at the next inspection" and "colonies alive at the next inspection" ($F = 1.02$; $p = 0.360$). The data was ranked and the rank means were compared with a Tukeys Standardized Range Test. The Minimum Significant Difference between the colonies dead at the sampling period and the colonies alive at the same time was 34.946 which is not significant at the 5% level. Consequently, in this honeybee population and during this monitoring period, while it could be concluded that varroa mites were negatively affecting honeybee colonies, it could not be concluded that varroa population levels in individual colonies were predictive of colony mortality.

Effect on Pollination Efficiency

Comparing the two groups of colonies used for pumpkin pollination, the varroacide-treated group and the untreated group, the data was normally distributed and standard t-tests (Least Significant Difference, LSD) were used. There was no significant difference in the numbers of frames of bees in the colonies (Table 3.7) but treated colonies had significantly more brood, and dramatically fewer varroa mites (Table 3.7; Students t-test, $p \leq 0.05$). The peak foraging period of the colonies on pumpkins in February was found to be between first light and 08h30, similar to that reported by Fell (1999). 07h00 was selected for the assessment of foraging rates and the untreated colonies were found to forage significantly more than the treated colonies (Table 3.7; Students t-test, $p \leq 0.05$). Foragers from both groups of colonies were found to be foraging primarily on pumpkin flowers with 71.1% of pollen foragers collecting pumpkin pollen. There were no significant differences between the treated and untreated groups as regards the collection of pumpkin pollen, other pollen, or total pollen collected (Table 3.7; Students t-test, $p \leq 0.05$). The fruit set percentage of the two groups was 75/100 for the flowers tagged adjacent to the treatment colonies, and 61/100 for the flowers tagged adjacent to the non-treatment colonies. While not statistically significantly different (chi-squared = 1.281, $p = 0.50$), the difference of 14% fruit set is of potential significance for growers.

In the second pollination trial, on apples, and comparing colonies with a light varroa load with treated colonies, the data was again normally distributed and a Least Significant Difference (LSD) t-test was used to compare treatment means. The treatment and control colonies were statistically significantly different in the numbers of varroa mites ($F = 1.3253$, $p \leq 0.05$) but were otherwise the same in terms of the amount of bees and brood (Table 3.8). Foraging rates between the groups were also not significantly different, and the apple fruit set percentages for the groups were also not significantly different, both for the blossom clusters adjacent to the hives and for the clusters further removed from the colonies. Clearly, these

untreated colonies with a low level of varroa mite infestation were as effective in the commercial pollination of apples as were colonies that had been treated to remove the mites.

Table 3.7: Comparison of the pollination efficacy of pumpkins by varroa-free or varroa-infested honeybee colonies. All colonies were from the same original apiary and of the same strength. 50% of colonies were chemically treated for varroa mites in November 1999. These as well as untreated colonies were placed into commercial pumpkins fields near Cape Town in February 2000. The mite load of all colonies was accurately determined. The average foraging rate of colonies was recorded daily for seven days. A total of 200 female flowers, all of which opened during those seven days, were tagged in the fields serviced by each of the treatment and control colonies (100 flowers per field). The percentage of these tagged flowers that yielded mature pumpkins was determined after six weeks.

		Frames of bees	Frames of brood	Varroa mites per 100 bees	Foraging rate per 2 minutes	Pumpkin pollen foragers	Other pollen foragers	Total pollen foragers
Varroacide treatment (n = 12)	Mean	9.8	4.6	0.1	37.4	19.3	7.5	26.8
	Standard error	0.13	0.22	0.05	4.11	2.08	1.35	2.74
No varroacide treatment (n = 12)	Mean	9.4	3.1	12.6	53.1	25.7	10.8	36.5
	Standard error	0.23	0.25	2.88	5.52	3.24	0.42	3.37
Students' t-test (p≤0.05)	LSD value	0.5465	0.6834	5.9636	14.267	12.141	4.4625	13.701
	Significance	ns	s	s	s	ns	ns	ns

Table 3.8: Evaluation of pollination efficacy of apples of varroacide treated and untreated colonies. Six varroacide treated colonies and six untreated colonies are placed around a large Golden Delicious orchard. The foraging rates of all colonies are recorded daily for two minutes, for a period of six days. The fruit set of 480 marked apple blossom clusters was monitored. Twenty of the clusters were placed in Golden Delicious trees immediately adjacent to each of the introduced colonies (within ten trees; Near To Bees) and twenty more of the clusters in the same rows of trees but 31-40 trees away from the colonies (Far From Bees). The fruit set percentage of these clusters was then determined.

		Frames of bees	Frames of brood	Varroa mites per 100 bees	Foraging rate per 2 minutes	Fruit Set in "Near to Bees" clusters	Fruit Set in "Far from Bees" clusters	Fruit Set in all clusters
Varroacide treatment (n =6)	Mean	10.00	5.08	0.00	74.17	48.67	52.67	50.67
	Standard error	0.00	0.30	0.00	10.73	5.91	3.96	5.10
No varroacide treatment (n = 6)	Mean	10.00	5.33	2.73	62.08	42.83	54.33	48.58
	Standard error	0.00	0.21	0.54	8.71	1.82	4.48	4.14
Students' t-test (p≤0.05)	LSD value		0.8178	1.3253	30.793	15.102	14.592	12.891
	Significance	ns	ns	s	ns	ns	ns	ns

Secondary Diseases & Pests

Tracheal Mites

The tracheal mite and varroa mite infestation in 96 colonies in six apiaries during 1999 and 2000 is presented in Table 3.9. The tracheal mite infestation level remained extremely low for the duration of the sampling period, and even decreased, despite practically all the colonies being heavily infested with varroa mites. Sampling was discontinued after September 2000 on the basis of the low tracheal mite numbers, and it was concluded that tracheal mites were not acting in concert with varroa mites in South Africa.

Table 3.9: Varroa and tracheal mite infestation levels in colonies of Cape honeybee. Varroa presence was determined by sieving 400 collected worker bees with the hot-water method. Twenty bees in each colony were dissected for tracheal mites.

	Apiaries	Number of colonies sampled	Number of colonies with varroa mite	Average varroa load (mites per 100 bees)	Number of colonies with tracheal mite	Number of bees with tracheal mite	Number of tracheal mites counted
May 99	6	96	95	11.4	2	5	59
Sept 99	6	95	94	23.85	0	0	0
March 00	6	91	91	16.42	0	1	1
Sept 00	6	85	85	12.11	0	0	0

Capensis Problem

The effort to investigate a possible relationship between Cape honeybee infestation of *Apis mellifera scutellata* colonies and varroa mite infestation of these colonies was terminated after only eight months, by which time 13 of the 20 colonies being monitored had died. Nonetheless, the data collected from these colonies during this period is presented in Table 3.10 and Figure 3.7. The varroa levels in the colonies increase and then decline, as does the percentage of Cape honeybees in the colonies. An analysis of variance was performed using Pearson's Product Moment Correlation Coefficients (Table 3.11). Colony size (amount of bees) was positively and significantly correlated with the amount of brood in the colonies ($p \leq 0.05$), as would be expected. Both colony size and brood levels were negatively and significantly correlated with the varroa loads of the colonies, and colony size was also correlated with the level of Cape honeybee infestation in the colonies. These data indicate that both the varroa mite and the Capensis Problem negatively impact on the vitality of Savanna honeybee colonies. However, there was no correlation between the varroa load of the colonies and either the number of Cape bees in the colony or the level of reproductive development of the Cape honeybees in the colony, indicating that varroa and Capensis problems were not acting in concert. There was no evidence that Savanna honeybee colonies already struggling with the Capensis Problem were more prone to varroa mite problems, or *vice versa*,

Table 3.10: Varroa mite (*Varroa destructor*) and Cape honeybee (*Apis mellifera capensis*) levels in colonies of the Savanna honeybee (*A.m.scutellata*). Colonies were monitored every two months for a period of eight months. The number of surviving colonies during each monitoring period is indicated by n. Varroa presence was determined by sieving 400 collected worker bees with the hot-water method. Twenty randomly collected bees from each colony were dissected for race determination. A worker is defined as *A.m.capensis* if the combined number of ovarioles is greater than 16. The percentage of the dissected workers with fully developed ovaries (= eggs) is also indicated.

		Frames of Bees	Frames of Brood	Varroa mites per 100 bees	Capensis workers (%)	Workers with developed ovaries (%)
May 1999 n=20	Mean	5.3	1.1	3.6	14.0	0.4
	Standard Error	0.45	0.13	0.47	2.71	0.27
July 1999 n=18	Mean	4.2	1.0	8.9	16.1	3.3
	Standard Error	0.45	0.12	0.90	3.30	1.34
Sept. 1999 n=16	Mean	3.9	2.5	9.2	16.3	5.0
	Standard Error	0.48	0.35	1.48	3.53	3.1
Nov. 1999 n=12	Mean	5.6	3.5	1.6	19.5	3.6
	Standard Error	0.49	0.46	0.26	3.01	2.66
Jan. 2000 n=7	Mean	7.4	3.8	2.6	10.0	18.6
	Standard Error	1.13	0.60	0.53	4.49	7.06

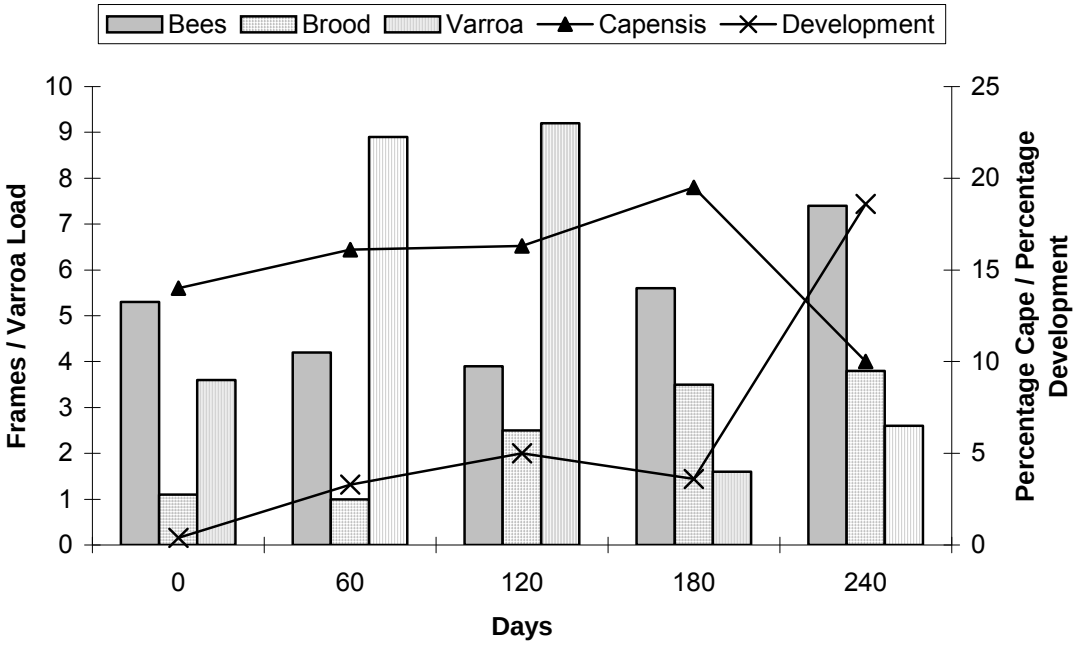


Figure 3.7: Varroa mite (*Varroa destructor*) and Cape honeybee (*Apis mellifera capensis*) levels in colonies of the Savanna honeybee (*A.m.scutellata*). Brood and bees are recorded as the number of frames in a colony, and varroa mites levels recorded as mites per 100 bees. Cape honeybees infestation is determined by the number of worker honeybees with a combined number of ovarioles greater than 16, in a sample of 20 randomly collected bees. The development of the Cape bees is determined by the percentage of the dissected workers with fully developed ovaries.

Table 3.11: Pearson's Product Moment Correlation Coefficients ($p \leq 0.05$) were used to test the relationship between colony size (frames of bees), amount of brood (frames), level of *Apis mellifera capensis* infestation (bees with combined ovariole numbers of greater than 16, in a random sample of 20 bees collected), the number of bees of this same sample that have mature ovaries, and varroa load (mites per 100 bees) in a commercial Savanna honeybee (*A.m.scutellata*) population. Statistically significant correlations are indicated with an asterisk.

	Colony Size	Brood	Capensis	Development
Varroa Load	r=-0.2595*	r=--0.2332*	r=-0.1114	r=-0.0363
	p=0.0266	p=0.0471	p=0.3513	p=0.7620
	n=73	n=73	n=72	n=72
Colony Size		r=-0.5512*	r=--0.3016*	r=--0.1085
		p<.0001	p=0.010	p=0.3643
		n=73	n=72	n=72
Brood			r=--0.2167	r=-0.0029
			p=0.0675	p=0.9809
			n=72	n=72
Capensis				r=-0.2082
				p=0.0792
				n=72

contrary to previous suggestions (Allsopp 1997b). Similarly, there was no evidence that either problem makes colonies less susceptible to the other problem. Interestingly, there was no significant correlation between the level of Cape honeybee infestation of colonies and the level of reproductive development in these colonies.

As with the varroa monitoring in the Cape commercial honeybee population, an effort was made to determine whether either varroa mite levels or Cape honeybee levels in these colonies were predictive of their imminent demise. The varroa loads, level of Cape infestation and level of reproductive development in colonies were compared between colonies that were dead at the next sampling period, and colonies alive at the next sampling period. The data is not normally distributed (Shapiro-Wilk $p < 0.0001$) and remained non-normal even after efforts to transform it with logit transformation (Snedecor & Cochran 1967) and by removing the outliers, and results remained the same as when using the original data. Therefore, the original data set was tested using a one-way ANOVA ($p \leq 0.05$). Colony mortality was found to be statistically and positively correlated with *Apis mellifera capensis* infestation ($F = 4.61$; $p = 0.035$) and with varroa load ($F = 4.96$; $p = 0.029$) but not with the level of reproductive development ($F = 0.00$; $p = 0.990$). These data strongly suggest that the numbers of Cape honeybees and the numbers of varroa mites in Savanna honeybee colonies was closely related to the mortality of these colonies but that the level of reproductive development of the Cape bees was not.

DISCUSSION

The expectation of many varroa researchers was that the varroa mite would not be a great threat in Africa, or to the honeybees of Africa, primarily because it was believed that the mites would not be able to reproduce sufficiently successfully in African honeybee colonies. The shorter developmental time exhibited by African races had been suggested to result in a larger degree of infertility in adult mite females after the invasion of worker brood (Camazine 1986; Ritter & De Jong 1984; Ritter *et al* 1990; Rosenkranz & Stürmer; Rosenkranz & Engels 1994; Aumeier *et al* 1996; but not Kirch & Rosenkranz 1998) or in injured or immature male mites (Martin *et al* 1997; Harris & Harbo 1999), thereby keeping the number of mites below the danger threshold and contributing to the relative tolerance of the African honeybee races. The mite, it was suggested, would only be able to reproduce in drone brood, limiting the population growth of the mite. In its original habitat, and with its original host (the Asian honeybee, which has an extremely short developmental period), the varroa mite has a balanced parasite-host relationship and does not cause any great damage (Boot *et al* 1997). Hence, the mite would not be a problem in Africa because the mite population would never reach the damage threshold.

From the estimates of the numbers of varroa mites present in both Cape and Savanna honeybee colonies, gathered during the varroa surveys (Appendix I; Table 3.1), it is clear that this expectation was not realized. Rather, *Varroa destructor* very rapidly built up to huge population levels in both Cape and Savanna honeybee colonies, with 30 000 – 50 000 mites per colony not being unusual (Appendix I; Table 3.1). These numbers are the highest infestation rates ever recorded, comparable with the worst-infected colonies in Mexico (Arechavaleta-Velasco & Guzmán-Novoa 2001), and much higher than generally reported in Europe or the Americas (Rosenkranz 1999; Vandame *et al* 2002; Martin 1997a). It is obvious that there was no immediate impediment to varroa mite reproduction in African honeybee colonies (both Cape and Savanna bees) and that the mite was able to reproduce very efficiently in African bees, at least initially. The expectation that African honeybees would keep mite numbers in check has therefore been shown to be false. While there is no general relationship between mite numbers and mortality (Martin 1997a), it is also apparent that both Cape and Savanna honeybee colonies are able to withstand varroa loads far in excess of that reported elsewhere. The economic thresholds for varroa collapse are considered to be 3 100 to 4 200 mites per colony in the USA, 2 000 to 15 000 mites in Spain, and 3 175 mites in Mexico (Bermajo & Fernádez 1997; Medina & Mejia 1999; Delaplane & Hood 1999).

These very large numbers of varroa mites caused the same damage in African honeybee colonies as has observed around the world. All the typical varroa symptoms (vestigial wings, malformed bees, dead pupae and adults in brood cells, spotty brood pattern) were all too apparent in both Cape and Savanna bees. Furthermore, at least at the front of varroa spread, when colonies were first exposed to the mite, large-scale mortality was caused in African honeybee colonies. In the comparison between untreated colonies

and colonies treated with a varroacide (Appendix II; Table 3.2) it is apparent that when left untreated, whole apiaries can succumb to the mite, and that the number of varroa mites was significantly correlated with colony death. This is statistically demonstrated in the colonies of the Western Cape where there are significant differences between varroacide-treated colonies and untreated colonies in colony strength (represented by the number of bees and the amount of brood present), varroa levels and in colony survival (Table 3.2), but not in the colonies monitored in Kwazulu-Natal. In these apiaries treated and untreated colonies were together in each apiary (except one), and the varroacide must have been transferred to untreated colonies to an unexpected extent. This resulted in a dramatic decrease in varroa numbers in the untreated colonies, to the extent that these colonies were not significantly different from the treated colonies in varroa load (Table 3.2). Nor was there any difference in the number of bees and the amount of brood between treated and untreated colonies, or in the survival of the colonies of the two groups.

This result, the transmission of varroacides within an apiary, is not without importance. Not only does it confirm the level of forager drifting in commercial apiaries (Allsopp 1992; Boylan-Pett *et al* 1997), for why else should varroa numbers have decreased so impressively in non-treated colonies, but it also has implications for the commercial use of varroacides, and in research on the efficacy of varroacides. Worldwide, a great deal of emphasis has been placed on the “proper” use of varroacides, which means using them as infrequently as possible and always at the correct dosage (Watkins 1996; Calderone 1999). If varroacides are transferred between colonies in an apiary, and their effect diluted in the untreated colonies, this would be expected to promote the development of varroacide tolerance in the mites, and would require beekeepers to always treat all colonies in an apiary at the same time. With the benefit of hindsight, this mistake was not made when testing for the effect of varroacide treatment on colonies in the Western Cape (Appendix II; Tables 11-14), or in later testing of the efficacy of various varroacides in South Africa. It should also be noted that the rapid recovery of the treatment groups readily indicated the efficacy of the varroacides used under South African conditions which was later confirmed with extensive efficacy testing for a number of commercially available varroacides (Allsopp unpublished data).

The limitation placed on the Kwazulu-Natal data by the use of mixed apiaries notwithstanding, the comparison of treated and untreated colonies in South Africa clearly demonstrated that varroa mites had a lethal effect on some colonies of both Cape and Savanna honeybees, with approximately 35% of colonies in the non-treatment group dying as a result of the mite infestation, but that there wasn’t the catastrophic population-wide collapse reported elsewhere. It is also certain that this mortality is due to varroa, simply because the varroacide-treated colonies don’t die, and this is the only difference in colony treatment. This varroa-induced mortality is not surprising as the mite in South Africa is the Korean haplotype of *Varroa destructor* (Anderson 2000), which has caused widespread mortality worldwide. Yet, even at the “front” of the varroa spread, an estimate of the percentage of commercial honeybee colonies (Savanna and Cape) dying due to the varroa mite would be no more that 40-50% of colonies, far removed from the 99%

population-wide mortality found in other parts of the world (Bailey & Ball 1991; Kraus & Page 1995b; Finley *et al* 1996; Loper 1996; Hunt 1998). Even in the most affected regions, and at the initial exposure to the varroa mite, many colonies did not collapse, although in almost all cases colonies exhibited symptoms demonstrating that they were negatively affected by the presence of the mites (Appendix II; Table 3.2). It is also worth noting that the time taken for colonies in South Africa to collapse is within two years of first exposure to the mite, perhaps resulting from the huge numbers of mites in some colonies (Table 3.1). Worldwide, the time taken for colonies to collapse from varroa mites is extremely variable, being as rapid as six months (Martin 1997a) or as long as seven years (De Jong *et al* 1982). Most colonies are expected to die 1-2 years after infestation begins (Bailey & Ball 1991).

The conclusion that some colonies (but only some) were succumbing to the varroa mite was supported by reports from many beekeepers in the Western Cape that they lost as many as 30% of their colonies in the second and third year after the detection of varroa mite in South Africa, and by the comprehensive monitoring of 473 commercial colonies in the Western Cape. These data indicated that varroa numbers were strongly negatively correlated with colony size, worker brood production, drone brood production, and pollen storage (Pearson Product Moment Correlation Coefficients), and positively correlated with time. All the measures of colony condition were positively correlated with each other but negatively correlated with time (Table 3.6). Hence, the numbers of varroa mites in commercial Cape colonies was shown to be increasing in the first years after varroa infestation (1999 and 2000), and this resulted in a reduction in colony strength and condition (Table 3.6). This negative impact on colonies did not necessarily result in the death of the colony, and colony mortality could not be correlated with varroa load (Tukeys Standardized Range Test). The lack of correlation between the level of varroa infestation and colony mortality confirms previous reports (Martin 1997a; Martin *et al* 1998; Martin 1998) and demonstrated the variation in response to varroa mite infestation of honeybee colonies. Perhaps a pattern would have developed if the monitoring programme had continued and it was unfortunate (although understandable) that the beekeepers retired from the programme in order to treat their colonies.

It is interesting that, while there was a gradual but clear increase in varroa numbers in Cape commercial honeybee colonies over time (Figure 3.4; Table 3.6), there was no obvious seasonal effect (Figure 3.5). Varroa numbers in colonies peak in November and December as might be expected, as this follows the peak drone production period in the Cape (Allsopp & Hepburn 1997), but the pattern was weak and there were huge fluctuations in varroa numbers between months (Figure 3.5). Perhaps this indicates that the monitoring of even 473 colonies is an insufficient sample size, but it more likely reflects the reality of two aspects of beekeeping in the Cape. Firstly, there is a continual replenishment of the commercial honeybee population by colonies trapped from the wild, most commonly in more remote regions. This means that any apiary is a mixture of colonies that have been hived for years (and exposed to varroa mites for all this time) and colonies that have just been trapped (and only now been exposed to the mite), and everything in

between. Hence, in the first years after the arrival of the mite in South Africa and before the mite had spread throughout the wild honeybee population (Chapter 2), the time of exposure was highly variable in commercial honeybee colonies, and this probably obscures any seasonal effect that might be present. The second reason why a seasonal effect was not obvious is that the beekeeping season in the Western Cape is highly variable. In areas of fynbos colonies peak in the late winter months (Allsopp & Hepburn 1997), following the typical winter rainfall, while in suburban and forestry regions colonies peak in January and February following the flowering of the dominant eucalypt species *Eucalyptus cladocalyx* and *E.camaldulensis* (Johannsmeier 2001). As the monitoring of 473 commercial colonies represented beekeepers in all regions of the Western Cape, it was not surprising that no seasonal effect was obvious.

Nonetheless, the monitoring of the commercial honeybee population confirmed earlier results; namely, varroa mites in the Cape were impacting on colony viability even if they were not causing population-wide colony collapse. The effort to determine if these varroa-infested colonies were less successful during commercial pollination was inconclusive and further trials in this regard will need to be completed if a definitive result is to be obtained. In the pumpkin trial, using colonies with a high varroa load, and bearing in mind that both groups of colonies (treated and untreated) foraged extensively on pumpkins, it is interesting that the treated colonies foraged less yet resulted in better pollination (Table 3.7). This perhaps reflects that foraging trips from the treated colonies were of longer duration (Kralj & Fuchs 2002), and perhaps more effective in effecting successful pollination. It is also possible that more foragers were being lost from the untreated colonies (Kralj & Fuchs 2002), requiring an increase in the numbers of foragers recruited to service the colonies' needs. The 14% difference in fruit set obtained between treated and untreated blocks was not statistically significant. The 75% fruit set in the treated blocks, however, is approximately the same as reported by Fell (1999), suggesting that this is a normal result and that the 61% fruit set found in the untreated blocks indicates insufficient pollination, or inadequate pollinators. This was most likely to be the result of these colonies being heavily infected with the varroa mite; only extensive further testing would confirm if this is indeed a valid conclusion. In comparison to the trial on pumpkins assessing colonies with a high varroa load, the second pollination trial on apples and using colonies with low varroa numbers, demonstrated no differences between treated and untreated colonies in terms of fruit set (Table 3.8).

Statistically significant or not, the 14% difference in pumpkin fruit set potentially represents approximately R2 500 per hectare to a grower, enough to indicate that colonies with a high varroa load should not be used for commercial pollination. As the value added to crop production by the commercial pollination of honeybees has been estimated to be in the order of R4.1 billion per annum (Chapter 1, Table 1) and this agricultural output sustains some 250 000 jobs, this is highly significant. Similarly, if the wild honeybee population pollinates as many as 40-70% of indigenous flowering plants, a reduction in pollination efficacy of varroa-infested colonies, even if they did not die due to the infection, would be of considerable concern.

As varroa mites have generally been described as weakening honeybee colonies and thus rendering them vulnerable to secondary infections (Bailey & Ball 1981; Martin 2001), an effort was made to determine what other factors might be contributing to colony mortality in conjunction with varroa infestation in South Africa. The same apiary in which tracheal mites were first found in South Africa (Buys 1995) was monitored for more than a year, as were other apiaries in the immediate vicinity. In 1997, 75% of the colonies had tracheal mites with 35% of bees having tracheal mites at an average of 9.3 mites per bee (Allsopp 1997b), a situation clearly more severe than had been the case when the tracheal mites had first been detected (Buys 1995). In 1999 and 2000, however, almost no tracheal mites could be found in any Cape honeybee colonies (Table 3.9) and as these colonies all had very substantial varroa mite infestations, this is strong evidence against any conjunctive action of the two types of mites in Cape honeybee colonies and that the Parasitic Mite Syndrome (Shimanuki *et al* 1994; Hung *et al* 1995; Hung *et al* 1996) is not in operation in South Africa. Similar results were found in Africanized bees in Arizona (Erickson *et al* 1998) and in Turkey (Çakmak *et al* 2003) where no significant interaction between tracheal mites and varroa mites was detected.

There was also no evidence that the Capensis Problem (Allsopp 1992) and varroa mites were acting in concert to cause the mortality of colonies in the *scutellata* regions of South Africa. While the colonies probably did not live long enough to provide a definitive answer, there appeared to be no correlation between the level of *capensis* infestation in these colonies and the number of varroa mites present in the colony (Table 3.11). There was, however, a significant negative relationship between colony size and amount of brood (= colony health) and both the numbers of varroa and the numbers of Cape bees in the colonies, but interestingly not with the level of ovary development in the Cape bees (Table 3.11). Hence, both varroa and Cape bee infestation were weakening *Apis mellifera scutellata* colonies, and both were predictive of impending colony mortality, but there was no relationship between the two. Also, surprisingly, there was no relationship between the numbers of Cape bees and the level of ovary development of these bees (Table 3.11). On the basis of these data the two problems are cumulative, but do not act in concert and there is no evidence that varroa is made more virulent by the Capensis Problem (Allsopp 1997b), nor that varroa is likely to result in the selective elimination of capensis-stressed colonies (Allsopp 1999).

As regards the other secondary infestations that are known to act in conjunction with varroa mites, namely chalkbrood and viruses, neither appeared to be of major concern in South Africa. Medina & Mejia (1999) report from colonies in Mexico that there is a significant correlation between the level of chalkbrood infestation and the collapse of a colony due to varroa mites, and a similar correlation was obvious as the varroa mite spread through South Africa. Where previously chalkbrood was relatively uncommon in commercial bee hives in SA in 1997 (Davison *et al* 1999), and had never been reported as a significant problem, it was suddenly prominent in almost all hives, in some cases to an extreme level. This

emergence of chalkbrood in colonies was, however, temporary in nature and soon disappeared or was reduced to non-significant levels. As chalkbrood is a general symptom of colony stress (Shimanuki *et al* 1992) it can be concluded that colonies that were naturally vulnerable to varroa mites exhibited severe chalkbrood problems which were not apparent in more varroa-tolerant colonies. As the vulnerable colonies soon collapsed and died, the prevalence of chalkbrood soon returned to pre-varroa levels. As such, chalkbrood probably contributed to the collapse of the vulnerable colonies, but at a population level its presence and effect was not of major concern.

Although a number of bee viruses have been found in South Africa (Benjiddou *et al* 2001), and Cape honeybee pupae and adults were found to be susceptible to virus infections (Johns *et al* in preparation), it was not possible to induce any bee viruses from Cape honeybee colonies (Johns *et al* in preparation), suggesting a general absence of bee viruses in the population. A similar situation was found in the honeybee population of Tunisia (Ritter 1990; Ducos de Lahitte *et al* 1998), where varroa mites have also not caused substantial honeybee mortality, and it is suggestive that the absence of these honeybee viruses might contribute to the relative tolerance to varroa that has been found in both South Africa and Tunisia.

In summary, the impact of varroa mites on the honeybee colonies of South Africa appears to have been largely transitory. In the initial stages of varroa spread and infestation, mite numbers in colonies were huge and most colonies were negatively affected, with the more susceptible colonies collapsing and dying. There was, however, no population-wide collapse of colonies, perhaps due to the relative absence of secondary pathogens, and the majority of honeybee colonies survived varroa mite infestation. Possible reasons for this tolerance are examined more closely in Chapter Five.

CHAPTER 4

POPULATION DYNAMICS OF VARROA MITES IN AFRICAN HONEYBEES

INTRODUCTION

Population growth in the natural host of varroa mites, the Eastern Honeybee *Apis cerana*, is limited by defence behaviours (Boecking & Ritter 1994) that are lacking in *A. mellifera*, leading to mite populations developing to enormous levels, and to colony collapses within 1-3 years. In *A.mellifera* yearly natural mite fall, and hence mite population levels, in the UK are reported to be between 10 000 and 60 000 mites (Martin *et al* 1998). Natural population growth rates have been shown to vary considerably (Bailey & Ball 1991) and this variance in population growth and resulting population size can be due to a vast range of factors, from the genetics of both the mites and the infected bees to environmental conditions or the seasons. Obviously, if mite mortality on adult bees and in the brood is less than the production of new mites in the brood, then the mite population will increase over time. A non-exhaustive list of factors influencing varroa mite population growth includes:

- The size of the initial mite population.
- Seasons and climactic conditions (Moretto *et al* 1997), which impact on brood levels and on mite reproductive rates. For example, *Apis mellifera carnica* in Brazil reportedly have much lower mite infestation rates than do *A.m.carnica* bees in Germany (Engels *et al* 1986).
- Host population dynamics. Mite population dynamics vary greatly with host population dynamics such as the brood/bees ratio, the amount of worker brood and the amount of drone brood (Ritter *et al* 1990; Fries *et al* 1991; Branco *et al* 1999; Calis *et al* 1999b; Beetsma *et al* 1999). The “normal” percentage of drone brood is commonly set at 4%, based on Allen (1965).
- The strain of bee, or more precisely, genetic differences between strains of bees (Otten & Fuchs 1990; De Guzman *et al* 1996; Vandame *et al* 2000). Obviously important factors would be drone brood development time, worker brood development time, drone brood post-capping time and worker brood post-capping time. African (Africanized) honeybees have long been considered to exhibit a degree of tolerance to varroa mites (e.g. De Jong *et al* 1984; Moretto *et al* 1991; Medina & Martin 1999), possibly because the population dynamics of the mites in African honeybee colonies is different from that in European honeybee colonies (Guzman-Novoa *et al* 1999). A slower natural mite population growth has been reported for Cape bees in comparison to European bees (Moritz & Mautz 1990), with the “mite population clearly restricted in development in Cape bees”.

- Mite invasion rate into both worker and drone cells (Boot *et al* 1995a) which depends on the number of available brood cells and on the number of bees in the colony.
- Mite reproductive success in worker brood and drone brood, which appears to be largely bee-race dependent (Fries *et al* 1994).
- Emergent mite mortality from worker and drone cells (Boot *et al* 1995b), with many of the daughter mites dying within a few days of emerging from a brood cell.
- Mite infertility in worker and drone brood, including the proportion of foundress mites dying in the brood cells, and the proportion of foundress mites producing only male offspring (Fries *et al* 1994).
- Possible defence of the hosts, including the uncapping of infected cells and direct aggression towards phoretic mites (Fries *et al* 1994).
- The rate of colony swarming.
- The number of times each mite is able to reproduce in its lifetime, which is 2-3 in natural colonies (Fries & Rosenkranz 1996; Martin & Kemp 1997).
- The amount of stored pollen or honey in the hive. Moretto *et al* (1997) report that successful mite reproduction is correlated with the amount of pollen in the hive. Medina & Martin (1999), however, did not find pollen linked positively to mite reproduction. Neither study found any correlation between mite reproduction and the amount of stored honey in a colony.

There have been many efforts to quantify and model mite population growth (Camazine 1988; Fries *et al* 1994; Boot *et al* 1994a; Boot *et al* 1995a; Martin 1998; Calis *et al* 1999b; Calis 2001; DeGrandi-Hoffman & Curry 2004), in an effort to understand and predict mite population dynamics, and these efforts and models have typically incorporated most of the factors influencing varroa population growth listed above. The models of Fries *et al* (1994) and Calis *et al* (1999b) are, for example, based on 23 reported studies on varroa mite reproduction. There are, however, surprisingly little actual field data recording mite population growth or monitoring mite numbers (e.g. Kokkinis & Liakos 2004), and few actual observations on mite build-up. An exception is Calatayud & Verdu (1995) who found exponential mite growth in *Apis mellifera iberica*, with the mite population doubling every 33 days. Among this plethora of variables, the key determinants in mite population dynamics are generally regarded as the brood infestation rate (of both worker and drone brood), the levels and ratio of brood in the colonies, the reproductive rate of varroa in both drone and worker cells (including mite mortality and mite infertility), and the number of reproductive cycles of mites (Fries *et al* 1994).

Brood infestation rates are very difficult to determine as they are dependent on a number of factors; the amount of brood present in the colony, the numbers of adult bees in the colony, the season, the number of mites in the colony, and the percentage of brood that is drone brood (Fuchs 1990; Boot *et al* 1994b; Boot *et al* 1995a; Martin & Kemp 1997). The brood infestation rate increases with the amount of suitable brood available, and decreases as the number of bees in the colony increases (Boot *et al* 1994b). What is apparent is that there is always a strong preference for drone brood over worker brood (De Jong 1984; Rosenkranz *et al* 1984; Otten & Fuchs 1988; Le Conte *et al* 1989; Fuchs 1990; Boot *et al* 1992). Drone brood is between 8.3 times (Fuchs 1990) and 11.6 times (Boot *et al*

1995a) more attractive than worker brood in European bees, with the attractive period of drone brood also being 2-3 times longer than that of worker brood (Ifantidis 1988; Boot *et al* 1992). Worker brood is attractive for invasion for 15-20 hours before cell capping (Boot *et al* 1994b) but most attractive to mites for the final 3 hours before cell capping (Calis *et al* 1997), and drone brood for 40-50 hours before cell capping (Boot *et al* 1992). This longer period of attractiveness explains, at least in part, the greater numbers of mites found in drone brood cells (Boot *et al* 1992) which are also preferred to worker brood when tested outside the colony (Le Conte *et al* 1989). Phoretic mites leave adult bees to enter the cells for reproduction when brought in close proximity of appropriately-aged brood cell (Boot *et al* 1994) and it has most often been concluded that brood aliphatic esters, especially methyl palmitate, are used by the varroa mites as signals to indicate the readiness of brood cells for invasion (Le Conte *et al* 1989). Trouiller *et al* (1991) extracted 17ng and 320ng methyl palmitate from the cuticle of worker and drone larvae respectively. However, Boot *et al* (1994a) were unable to increase the attractiveness of worker larvae by the addition of various amounts of methyl palmitate.

The uncertainty as regards brood infestation rates notwithstanding, both in terms of temporary fluctuations and causality, in Africanized bees rates of between 8 – 17% have been reported for worker cells and 33% for drone cells (Medina & Martin 1999; Garrido *et al* 2003). Figures for European bees are not noticeably different, with between 11% and 20% reported for worker brood and 27% for drone brood (Marcangeli *et al* 1992; Garrido *et al* 2003). There is no evidence that some mites favour one type of brood (worker or drone) over the other (Radtke 1997).

There is also great difficulty in quantifying mite reproductive rates in worker and drone brood. The method that has generally been used is to insert mites (collected in some manner from the same or another colony) into brood cells, and then to re-open the cells immediately prior to the emergence of the adult bee, and record the mite offspring in the cell. Obvious experimental difficulties are as follows: (a) The condition of introduced foundress mites (mothers) is impossible to control. A mite might be callow, or have just reproduced. It may have reproduced once or a number of time (de Ruijter 1987). The time spent by mites between reproductive cycles is largely un-researched and is poorly understood. It may not have produced any offspring or may have reproduced several times already. (b) The insertion of foundress mites into cells is based on the assumption that they are ready to reproduce, when this will often not be the case. At the very least, introduced foundresses will begin reproduction some hours after foundresses that invaded cells naturally. (c) Finding and counting mite males and exuviae in emerged brood cells is extremely difficult, and subject to error. (d) The brood cells are often damaged during the insertion process, with the nurse bees re-opening the cells and removing the honeybee larvae.

These difficulties notwithstanding, it has generally been concluded that the reproductive rate of varroa mites in European bees is between 2.5 and 4.2 mature offspring produced in every infested drone cell, and between 1.0 and 1.6 mature offspring produced in every infested worker cell (Moosbeckhofer *et al* 1988; Blum 1989; Fuchs & Langenbach 1989; Beetsma & Zonneveld 1992; Fries *et al* 1994; Martin

1994; Martin 1995a; Martin 1997b; Calis 2001). As would be expected, reproductive rates in African bees are less than those found in European bees, with between 0.86 and 1.32 mature offspring produced in every infested worker cell (Camazine 1986; Medina & Martin 1999; Calis 2001; Martin & Kryger 2002). These differences are clearly due largely to the shorter development time found in African worker brood as there are no differences in the numbers of eggs laid by varroa in European and African bees, or the numbers of immatures produced in European and African (Africanized) worker cells (Rosenkranz & Engels 1994; Guzman-Novoa *et al* 1996; Medina & Martin 1999). In addition, mite development time is independent of bee race (Martin 1997b).

The population dynamics of *Varrroa destructor* in *Apis mellifera capensis* and *A.m.scutellata* were investigated, by examining the brood infestation rate, mite reproduction rate, and mite reproductive fate in both worker and drone brood of two honeybee races, as well as by directly monitoring mite population dynamics in honeybee colonies of both races. Possible reasons for poor reproduction and poor population growth in African honeybees, that is, factors resulting in possible mite tolerance, are examined in Chapter 5.

MATERIALS & METHODS

Varroa population growth in *Apis mellifera scutellata* and *Apis mellifera capensis*

Varroa destructor population growth was investigated in fifteen colonies of Cape honeybees (*Apis mellifera capensis*) in Stellenbosch and ten colonies of Savanna honeybee (*A. m. scutellata*) in Richmond, Kwazulu-Natal. All colonies had been trapped within the previous twelve months, and hence were expected to have low levels of mite infestation, and not to have been varroa-infested for any length of time. Both sets of colonies were maintained in isolated apiaries without other colonies of bees.

In March 2001 (for Stellenbosch) and April 2001 (for Richmond) all colonies were transferred into new hive-boxes equipped with standard varroa screens, and placed on stands with ant barriers (Plantex, UAP South Africa) to prevent access to the colonies by ants. The varroa screens had a hardboard base covered with 3 x 3 mm gauze that allows mites to fall through, but prevents bees from getting through. All debris including dead mites from the colony is collected on the varroa screens. A worker sample was removed from the brood nest of each colony for varroa determination using the hot-water method (Chapter 1). Four Bayvarol strips (Bayer SA) were then placed into each colony and left for a period of six weeks to eliminate all mites in the colonies. After this period basic data was collected from all colonies (colony strength, frames of drone and worker brood, frames of stored pollen and stored honey, queen presence, queen cells, bee diseases) and a worker sample was removed from the brood nest of each colony for varroa determination using the hot-water method to confirm the absence of varroa mites in the colonies. The Bayvarol strips were removed from the colonies and the colonies were then left for two weeks to settle.

Live varroa mites were collected in both Stellenbosch and Richmond by opening sealed brood collected from a colony with a high varroa load and removing adult mother mites. In each region varroa were collected from only one colony. Twenty mites were introduced into each colony to be monitored. Mites were introduced by being allowed to run onto a frame of open brood removed from each colony, and and allowed to disappear into the brood cells of the frame, which was then replaced in the colony.

Colonies were monitored every two weeks for twelve months, with the varroa screens being removed from each colony and all fallen female mites (dead or alive) being counted. Each varroa screen was cleaned and returned to the colony within three hours of having been removed. Once a month basic data was collected from all colonies (colony strength, frames of drone and worker brood, frames of stored pollen and stored honey, queen presence, queen cells, bee diseases). After twelve months four Bayvarol strips (Bayer SA) were introduced into each surviving colony and mite fall on the varroa boards counted every second day for two weeks. Two Apivar strips (Biové, France) were then introduced into each colony, to ensure that should there be mites resistant to one acaracide that they would be removed by the second. After a further two weeks both the Apivar and Bayvarol strips were removed, and the monitoring terminated. Two colonies in the Stellenbosch group were sealed and frozen. All worker bees were washed out of the colony with warm water, and all brood cells washed with warm water. The water and debris from each colony was washed through a standard varroa sieve (Chapter 2) and all varroa mites counted.

As additional controls, to determine the efficacy of the varroa screens and to investigate the assumption that the mite fall counted on the varroa screens approximates actual mite fall in the colonies, marked dead mites were sifted onto the screens which were left for five days before counting and dead mites marked a different colour were placed on the top bars of colonies to determine what percentage were captured in the varroa screens after five days. Six Stellenbosch colonies were used twice each in July 2002. On each occasion twenty black-marked dead mites were sifted onto the varroa screens of each of the six colonies, which were then replaced under the colonies, and twenty red-marked dead mites were carefully dropped onto the tops of the brood frames of each colony. Colonies were left for five days after which all marked mites found on the varroa screens were recovered and counted.

Brood cell infestation rates and mite reproduction rates in *Apis mellifera capensis*

During the summer months of 1999 and 2000, colonies of Cape honeybees in Stellenbosch were examined and colonies with both sealed worker and drone brood selected to determine the relative attraction of the different brood cells to varroa mites in Cape honeybees, and the levels of infestation in the two types of brood. The number of frames of bees in the colony was recorded using standard methods (Chapter 3), and amount of drone and worker brood carefully recorded in square inches using a counting frame (Allsopp & Hepburn 1997). A sample of worker bees was collected from the

brood nest from each of these colonies and the varroa load in each colony determined by sieving and counting mites and bees by the hot-water method (Chapter 2). All colonies had low or medium levels of *Varroa destructor* infestation, and none of the colonies had ever been treated with varroacides.

All frames containing sealed brood from each colony were removed to the laboratory. A region of sealed brood containing only larvae or white-eyed pupae was selected in each colony, this being determined by opening cell cappings to determine the age of the brood below. Brood of this age was selected as it removed any possibility of daughter mites being misidentified as mother (foundress) mites. A total of 200 worker cells and a total of 200 drone cells at this stage of development, or as many of each as were available in each colony, were then carefully open with a scalpel and forceps and the larva or pupa in the cell removed. The number of varroa mites on the larva or pupa was carefully counted. Each empty cell was carefully examined with a Fibre Optic Illuminator and any mites remaining in the cells were removed and counted. The level of mite infestation of worker and drone brood was then determined.

By way of comparison, frames of brood were removed from colonies in Stellenbosch in June and July 1999 and 2000, a time of the year when no drone brood is present in the colonies. The level of mite infestation in the worker brood during mid-winter was determined as described above. In addition to the 34 summer colonies examined, above, data was collected from a total of 11 winter colonies.

The frames of brood that were removed from the colonies (both in winter and summer) were also examined from worker and drone brood cells in which the occupant was a fully developed bee (worker or drone), about to emerge. These are brood cells in which the mite reproductive cycle is considered to be complete, and cells that can be used to determine the mite reproductive rates for the two types of brood cells. A total of 200 worker cells and a total of 200 drone cells at this stage of development, or as many of each as were available in each colony, were then carefully open with a scalpel and forceps and the larva or pupa in the cell removed. The number of varroa mites on the larva or pupa was carefully counted. Only adult female mites were counted, these being the typically brick-red mother mites or the typically tan-coloured daughter mites. Each empty cell was carefully examined with a Fibre Optic Illuminator and any mites remaining in the cells were removed and counted. Brood at the appropriate stage (emergent brood) was found in 33 of the colonies examined, for worker brood, and 21 colonies for drone brood. The numbers of adult female mites found in emergent drone and worker brood cells in Cape honeybee colonies, hence the reproductive rate of *Varroa destructor* in *Apis mellifera capensis*, was then determined.

Statistical Analysis

The varroa population growth in *Apis mellifera scutellata* and *Apis mellifera capensis* and the reproductive rate of varroa in Cape honeybees were not examined statistically, as no statistical analysis was considered to be appropriate or possible. Brood infestation data was, however, analysed using the programme Statistical Analysis System (SAS), version 8.2, 1999. The relationship between

the amount of worker brood and the amount of drone brood, and varroa infestation rates, was examined using Pearson's Product Moment Correlation Coefficients ($p \leq 0.05$).

RESULTS

Varroa population growth in *Apis mellifera scutellata* and *Apis mellifera capensis*

The complete data from the Stellenbosch and Richmond colonies is presented in Appendix IV. Three of the Richmond colonies were vandalized during the first month, and removed from the apiary. The monitoring in Kwazulu-Natal was therefore with seven colonies until the last two months when a further four colonies were lost due to the Capensis Problem (Allsopp 1993). A total of four of the *Apis mellifera capensis* colonies were lost during the monitoring period, with these colonies being lost due to starvation, or queen loss following swarming (Appendix IV). A further four colonies were lost to starvation at the end of the monitoring period.

The basic demographic data collected during the monitoring period is presented in Figures 4.1 (Stellenbosch) and 4.2 (Richmond), as well as in Appendix IV. Colonies in Stellenbosch appeared not to decrease in strength during the course of the monitoring period, the only decrease being seasonally related. By contrast, the colonies in Richmond were strongest at the onset of the monitoring period, decreased rapidly in strength, and thereafter remained at constant strength. No obvious impact of increased mite numbers or population growth could be seen in either group of colonies during the course of the year.

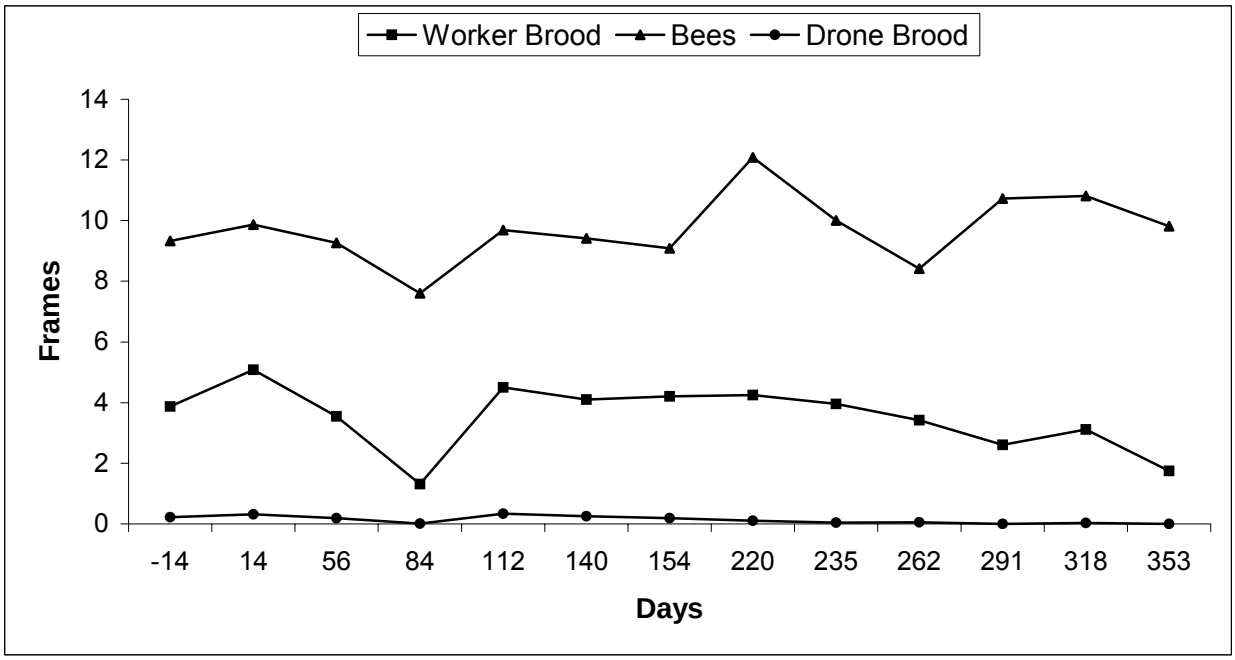


Figure 4.1: Mean number of frames of worker bees, worker brood and drone brood in the Stellenbosch colonies (*Apis mellifera capensis)* over the course of the monitoring period.

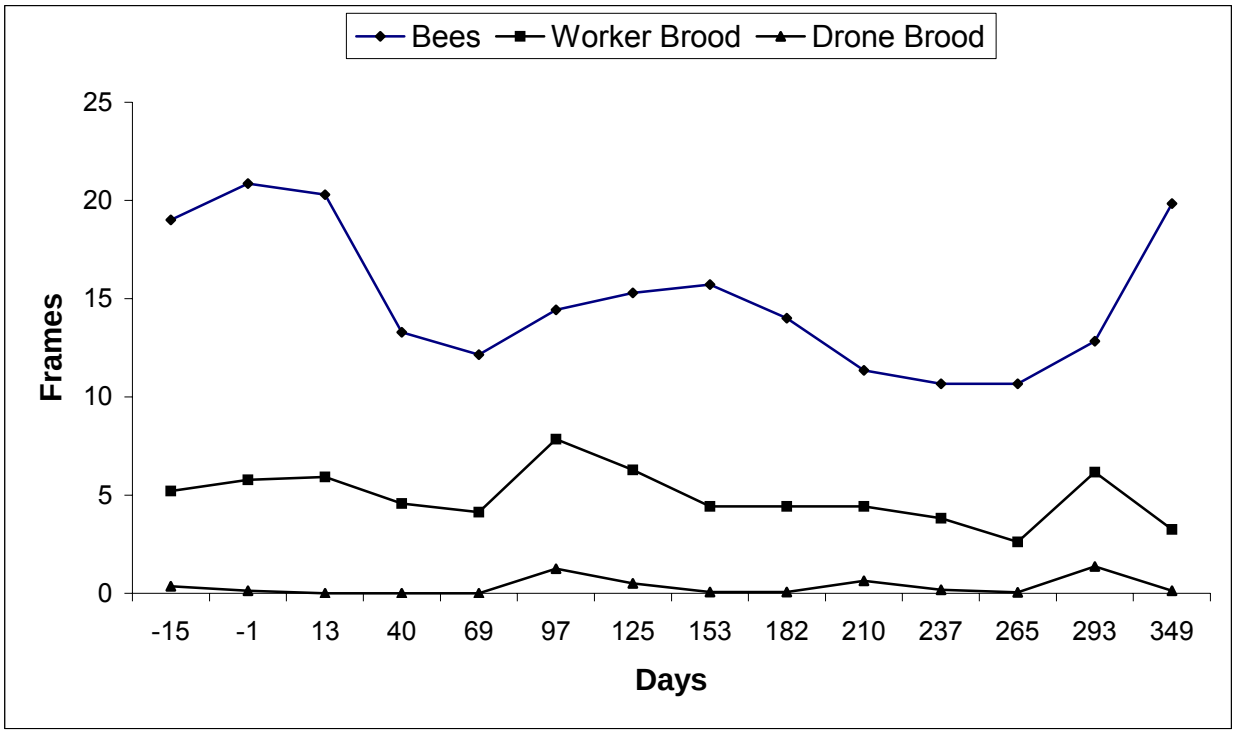


Figure 4.2: Mean number of frames of worker bees, worker brood and drone brood in the Richmond, Kwazulu-Natal colonies (*Apis mellifera scutellata*) over the course of the monitoring period.

Mite population levels for the colonies are recorded in Appendix IV and in Figures 4.3 and 4.4. In the Stellenbosch colonies mite fall increased slowly to reach 1.6 mites per colony per day after 120 days. At this stage mite fall in these colonies decreased sharply and remained at approximately 0.2 mites per colony per day until day 402 when varroacides were added to the colonies. Only 792 mites were removed by the acaracides from the remaining 7 colonies, an average of only 113 mites per colony fourteen months after the first introduction of 20 mites per colony.

Two of the remaining Stellenbosch colonies were sealed after the completion of the monitoring period, and frozen to kill all live bees and brood. The contents of these two colonies were then carefully washed out of the cells and frames with warm water, and all the adult bees and immatures rinsed through a varroa sieve (Chapter 2) with warm water to collect any mites remaining in the colonies. Only 5 mites were found in one colony and 2 in the other, confirming the efficacy of the varroacides used to drop mites at the end of the monitoring period, and the reliability of the collected data.

In the *Apis mellifera scutellata* colonies in Richmond, the mite population increased slowly but steadily, reaching a mite fall of about 3 mites per colony per day after 260 days. The mite fall then increased very rapidly up to approximately 50 mites per colony per day after 350 days. In these colonies there was no indication of a decrease in mite fall as there had been in the Stellenbosch *A. m. capensis* colonies, and mite population growth fitted the exponential model reported for *Varroa destructor* in Europe and the USA (Martin 1998). Four of the Richmond colonies unfortunately collapsed due to infestation by Cape honeybee parasitic workers (Allsopp 1993) at the end of the monitoring period,

with only 3 colonies remaining. A total of 2416 mites were recovered after the acaracide treatment of these 3 colonies, indicating a mite population of 805 mites per colony fourteen months after the first introduction of 20 mites into these colonies, approximately 700% more than were found in the Cape honeybee colonies. These data suggest a striking difference in the ability of *Varroa destructor* to reproduce in two races of honeybees found in South Africa (Figure 4.5). The data suggest that the mite reproduces more readily in *Apis mellifera scutellata*, much as the case in other races of *mellifera*, but that there is some inhibition or control of mite reproduction in Cape honeybees. Furthermore, this control appears to take effect after as little as 4 months of mite infestation, and with the mite population in the colonies at a very low level.

To determine the efficacy of the varroa screens in collecting dead mites, and the removal of dead mites from the varroa screens, marked dead mites were placed in the varroa screen, or sifted into the colony. An average of 13.8 mites were recovered from the 20 placed in the screens (n = 12; se = 1.06) and 14.9 mites from those left on the top bars (n = 12; se = 0.75). These data indicate that the vast majority of mites dying in the colony end up in the varroa screen, but that approximately 30% of mites in the screen are lost. As these mites cannot be removed by bees as they cannot access the varroa screen, other scavengers in the hives must be responsible. As ants were prevented from getting into the hives, the most likely scavengers are pseudoscorpions and the small hive beetle *Aethina tumida*, both of which have been seen removing dead varroa mites (personal observations). If only 70% of mites falling onto the screens are recovered after five days, this suggests that a higher percentage would be removed during the two-week monitoring periods, perhaps as much as 50%.

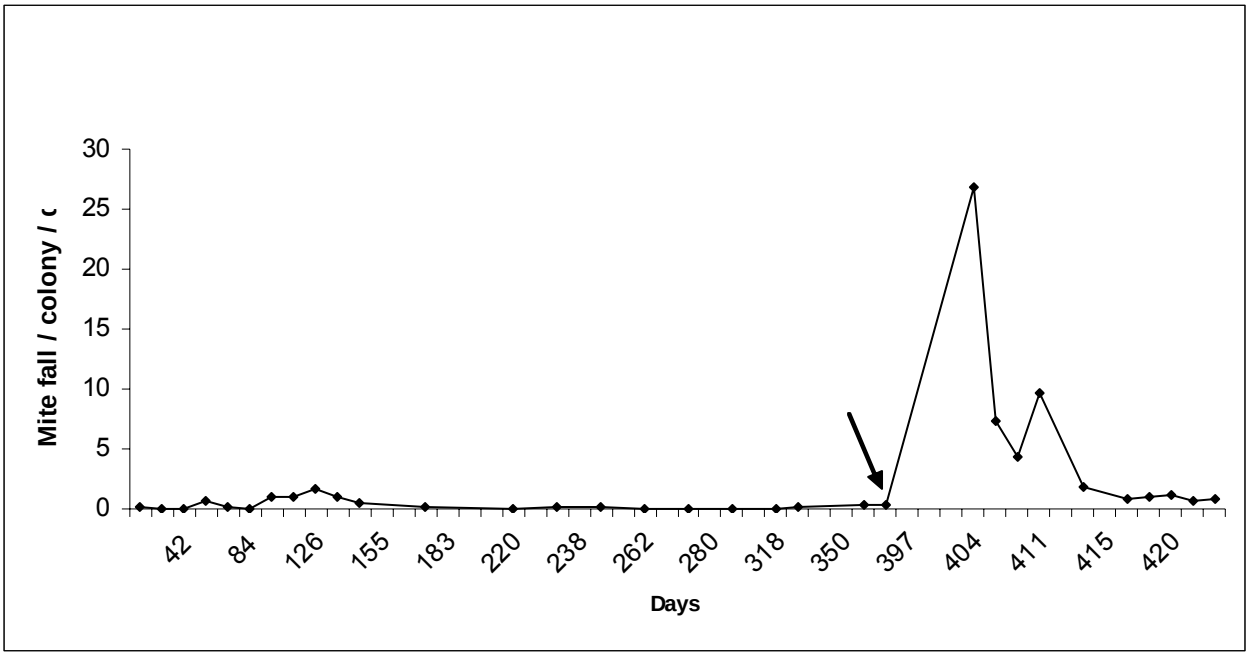


Figure 4.3: Varroa mite population growth in *Apis mellifera capensis* colonies. Mite fall per colony per day is indicated for the Stellenbosch colonies. Colonies are cleaned of varroa mites at the beginning of the monitoring period, and thereafter 20 mites are added per colony. Mite fall is recorded on varroa screens approximately every fortnight. Bayvarol (Bayer SA) was added to the colonies after 402 days, and Apivar (Biově) after 416 days. Mite fall after the arrow is caused by the application of varroacides.

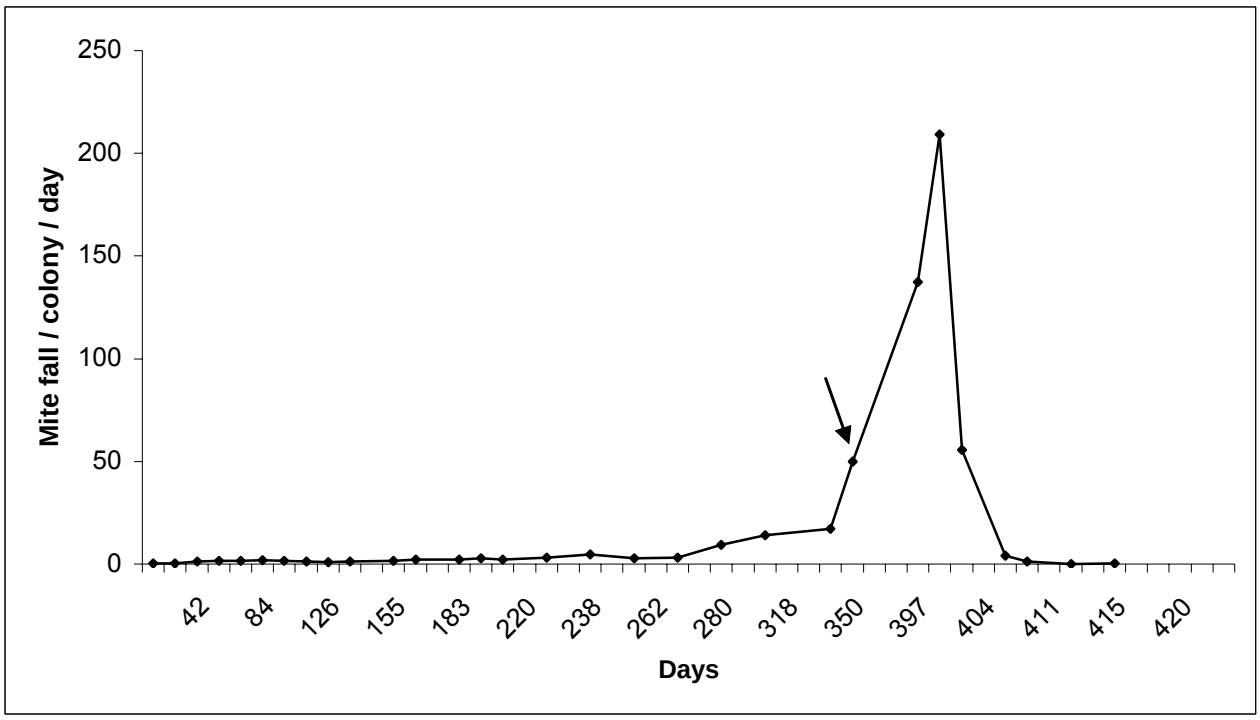


Figure 4.4: Varroa mite population growth in colonies of *Apis mellifera scutellata*. Mite fall per colony per day is indicated for the Richmond colonies. Colonies are cleaned of varroa mites at the beginning of the monitoring period, and thereafter 20 mites are added per colony. Mite fall is recorded on varroa screens approximately every fortnight. Bayvarol (Bayer SA) was added to the colonies after 394 days, and Apivar (Biově) after 406 days. Mite fall after the arrow is caused by the application of varroacides.

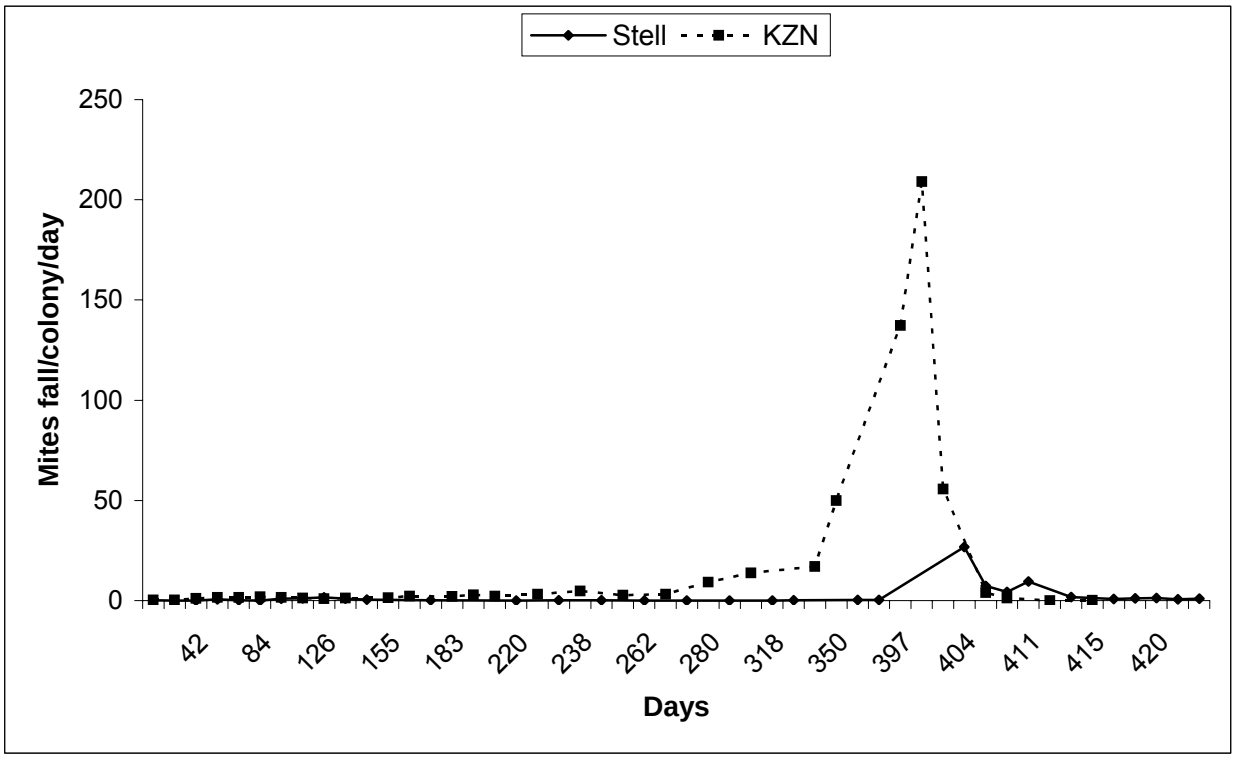


Figure 4.5: Comparison of *Varroa destructor* population growth in colonies of *Apis mellifera capensis* and *Apis mellifera scutellata.*

Brood cell infestation rates and mite reproduction rates in *Apis mellifera capensis*

Varroa mites are found to successfully infest both worker brood and drone brood in Cape honeybees. The summer (with both worker brood and drone brood present) brood infestation rates of varroa in Cape bees, based on 34 colonies and 9300 cells examined, are presented in Table 4.1. The use of cells with only larvae or very young pupae present removes the possibility that daughter mites are counted, and limits mites counted to foundresses, and hence the infestation rate of the cells. Colonies had a low average varroa load (varroa mites per 100 bees) of 3.67. The basic worker brood infestation rate is 6.2%; that is, the percentage of worker cells with varroa mites (one or more) present. Taking into account that there are multiple foundresses in some cells, the true brood infestation rate (that is, number of varroa mites per worker cell, indicated as a percentage; therefore, mites per 100 worker cells), is found to be 7.9. The equivalent figures for drone brood are 25.3% (percentage of drone cells infested) and 48.6 (number of mites per 100 drone cells) (Table 4.1). Equivalent data was collected from 11 colonies during the winter months, when only worker brood is present (Table 4.2). The varroa load in these colonies is reduced in comparison to summer colonies, as expected, as is the amount of worker brood in the colonies (Table 4.2). The worker brood infestation rates are only slightly higher than those of the summer colonies, despite there being no drone brood available, being 7.4% of worker cells infested and 8.3 mites per 100 worker cells.

Fuchs (1990) found that the brood infestation rate increases with the percentage of drone brood present and with the total amount of brood present. In addition, the brood infestation ratio (drone brood infestation: worker brood infestation) increases with the percentage of brood that is drone brood, but is unaffected by the varroa load or by the total amount of brood. The correlation between these factors is examined in the summer brood infestation data (Table 4.1). Colonies in which less than 30 cells of both drone and worker brood were available to be examined were removed from the data set, as these were considered as having too little brood to give an adequate sample size. In addition, colonies X02 and X01 were removed from the data set, as brood data for these colonies were not collected. A total of 23 colonies remained in the data set for analysis. Finally, in the determination of brood infestation ratios (drone:worker), as this could not be calculated in colonies were the worker brood infestation rate was 0, the ratio in these colonies was estimated to be double that of the drone infestation rate. These data are presented in Table 4.3. and the relationships between varroa load, total amount of brood and percentage of brood that is drone brood, and worker infestation rate, drone infestation rate and the ratio between drone and worker infestation rates is presented in Table 4.4. The extent of varroa infestation is found to be significantly correlated with both the worker brood infestation rate and the drone brood infestation rate, but does not influence the brood infestation ratio. The total amount of brood in the colony does not correlate with worker brood infestation rates, drone brood infestation rates or the brood infestation ratio and the percentage of drone brood present does not result in an increase in the brood infestation rate or in the brood infestation ratio. Rather, an increase in the percentage of drone brood in Cape honeybee colonies results in a decrease in worker brood infestation rate, but also in a decrease in drone brood infestation rate (Table 4.4).

Table 4.1: Brood infestation rates in summer colonies of Cape honeybees. Sealed worker and drone brood cells containing larvae or white eyed pupae are examined for varroa mites, to a maximum of 200 cells per brood type per colony.

Colony	Varroa mites per 100 bees	Square inches of sealed brood		Worker brood infestation					Drone brood infestation				
		Worker brood	Drone brood	Number of cells examined	Number of varroa infested cells	% infested cells	Number of varroa in cells	Brood infestation rate (mites per 100 cells)	Number of cells examined	Number of varroa infested cells	% infested cells	Number of varroa in cells	Brood infestation rate (mites per 100 cells)
64	4.7	115	18	200	14	7.0	20	10.0	134	40	29.9	54	40.3
22	1.4	347	13	200	14	7.0	14	7.0	200	83	41.5	130	65.0
84	0.5	136	4	200	3	1.5	3	1.5	9	0	0	0	0
104	2.4	113	6	94	3	3.2	3	3.2	7	0	0	0	0
94	2.3	185	2	200	12	6.0	20	10.0	2	0	0	0	0
108	0.0	241	2	200	11	5.5	13	6.5	4	0	0	0	0
107	2.8	358	26	200	4	2.0	4	2.0	72	12	16.7	17	23.6
217	4.4	304	32	200	0	0	0	0	101	13	12.9	15	14.9
331	1.4	360	24	200	7	3.5	8	4.0	135	10	7.4	11	8.1
XX1	2.1	376	45	120	18	15.0	20	16.7	23	5	21.7	6	26.1
76	4.6	542	75	200	14	7.0	14	7.0	26	13	50.0	17	65.4
98	3.7	56	11	200	100	50.0	149	74.5	3	0	0	0	0
106	1.5	299	16	85	1	1.2	1	1.2	15	0	0	0	0
105	5.5	334	41	200	7	3.5	7	3.5	200	47	23.5	65	32.5
342	10.0	292	5	200	20	10.0	30	15.0	193	144	74.6	489	253.4
96	6.8	179	6	152	13	8.6	16	10.5	165	34	20.6	49	29.7
12	4.4	237	2	200	7	3.5	8	3.5	17	1	5.8	2	11.8
602	1.0	282	25	200	9	4.5	9	4.5	57	12	21.0	16	28.1
X02	7.5	-	-	97	10	10.3	11	11.3	34	21	61.8	49	144.1
X01	6.9	-	-	142	21	14.8	30	21.1	76	38	50.0	90	118.4
75	0.9	178	27	200	1	0.5	1	0.5	200	35	17.5	38	19.0
517	1.7	205	29	200	0	0	0	0	31	3	9.7	3	9.7
518	2.6	211	32	165	8	4.8	8	4.8	75	4	5.3	4	5.3
344	9.4	343	47	200	8	4.0	8	4.0	96	48	50.0	95	99.0
259	4.3	310	32	102	10	9.8	10	9.8	90	29	32.2	40	44.4
8	2.0	304	17	200	9	4.5	9	4.5	60	9	15.0	10	16.7
14	3.9	217	4	200	10	5.0	10	5.0	41	28	68.3	60	146.3
20	0.4	137	14	200	1	0.5	1	0.5	200	32	16.0	35	17.5
109	0.5	437	18	200	1	0.5	1	0.5	30	0	0	0	0
258	7.0	256	21	200	15	7.5	17	8.5	66	37	56.1	87	131.8
15	0.0	141	22	200	0	0	0	0	200	5	2.5	5	2.5
42	8.0	346	18	200	30	15.0	35	17.5	200	40	20.0	59	29.5
70	6.7	252	50	200	3	1.5	4	2.0	200	55	27.5	90	45.0
17	3.4	228	22	200	0	0	0	0	200	2	1.0	2	1.0
TOTALS	3.67 (ave)	260 (ave)	22.1 (ave)	6157	384	6.2	484	7.9	3162	800	25.3	1538	48.6

Table 4.2: Brood infestation rates in winter colonies of Cape honeybees. Sealed worker brood cells containing larvae or white eyed pupae are examined for varroa mites, to a maximum of 200 cells per colony.

Colony	Varroa mites per 100 bees	Square inches of sealed brood		Worker brood infestation				
		Worker brood	Drone brood	Number of cells examined	Number of varroa infested cells	% infested cells	Number of varroa in cells	Brood infestation rate (%)
11	4.3	33	0	200	23	11.5	25	12.5
55	1.3	234	0	200	4	2.0	5	2.5
33	1.6	143	0	200	3	1.5	3	1.5
5	3.8	7	0	200	37	18.5	38	19.0
21	0.8	62	0	200	15	7.5	16	8.0
2	5.9	115	0	200	27	13.5	36	18.0
65	1.2	56	0	200	21	10.5	23	11.5
1	0.0	91	0	136	1	0.7	1	0.7
340	1.2	304	0	117	15	12.8	18	15.4
16	0.2	269	0	200	1	0.5	1	0.5
13	2.3	160	0	200	5	2.5	5	2.5
TOTALS	2.1 (ave)	134 (ave)	0 (ave)	2053	152	7.4	171	8.3

In the assessment of the reproductive rate of varroa mites in Cape honeybees, relatively few appropriately-aged cells were found infested with varroa mites. Only 4 554 appropriately-aged worker cells (from a total of 33 colonies) and 1608 appropriately-aged drone cells (from a total of 21 colonies) could be found, yielding 296 worker cells (6.5%) and 365 drone cells (22.7%) infested with varroa mites. This is because only cells where the developing bee (worker or drone) was about to emerge were chosen for this assessment, and these cells are relatively few in any colony at any moment in time. The choice of these appropriately-aged cells is important, however, as these cells represent the natural completion of the varroa mite reproductive cycle, and are the only cells in which varroa mite reproductive development can be accurately determined.

A total of 513 mites (either brick-red or tan, but always fully developed and considered as adult female mites) were found in the 296 worker cells, or 1.73 mites per emergent cell (Table 4.5). Assuming only one foundress per cell, and no death of the foundresses in the cells, this represents the production of 0.73 mature female mite offspring per worker brood cell. The brood infestation rate data for Cape honeybees (Table 4.1) indicates that 20.7 of foundress mites in worker brood cells are multiple foundresses, indicating that the actual reproductive rate in worker brood cells in this Cape honeybee population is likely to be less than 1.38 or 0.38 mature female mite offspring per foundress. 1323 mites (again either brick-red or tan, but always fully developed and considered as adult female mites) were found in the 365 drone cells, or 3.62 mites per emergent cell (Table 4.5). If there was only one foundress mite per drone cell, and no death of the foundresses in the cells, this would represent the production of 2.62 mature female mite

offspring per drone cell. Correcting for the brood infestation data (Table 4.1) which indicates 48% of foundress mites in drone brood are multiple foundresses results in an actual reproductive rate in drone brood cells of Cape honeybees of no more than 1.88 or 0.88 mature female mite offspring per foundress mite.

Table 4.3: Brood infestation rates in summer colonies of Cape honeybees. Sealed worker brood cells containing larvae or white eyed pupae are examined for varroa mites, to a maximum of 200 cells per colony. Colonies with less than 30 cells of both drone and worker brood, and colonies without records of the amount of brood present, have been removed from the overall data set.

	Varroa Load	Total Brood	% Drone Brood	Worker Infection Rate	Drone Infection Rate	Ratio: Drone – Worker Infection rate
n	23	23	23	23	23	23
Mean	3.86	290.30	8.51	4.96	46.2	12.81
Standard Error	0.80	18.26	0.88	1.03	12.48	2.48

Table 4.4: The relationships between varroa load (mites per 100 bees), total amount of brood and percentage of brood that is drone brood, worker infestation rate, drone infestation rate and the ratio between drone and worker infestation rates in the commercial Cape honeybee population during summer months (n = 23 colonies). Statistically significant correlations (Pearson's Product Moment Correlation Coefficients, $p \leq 0.05$) are indicated with an asterisk.

	Worker Infection Rate	Drone Infection Rate	Ratio: Drone – Worker Infection rate
Varroa Load	r = 0.643 p = 0.009*	r = 0.639 p = 0.001*	r = 0.057 p = 0.797
Total Brood	r = 0.049 p = 0.824	r = 0.014 p = 0.949	r = -0.247 p = 0.256
% Drone Brood	r = -0.447 p = 0.032*	r = -0.414 p = 0.050*	r = 0.207 p = 0.344

Table 4.5: Numbers of adult female mites found in emergent drone and worker brood cells in Cape honeybee colonies.

	Number of cells with mites	Number of mites	Average number of mites per emergent cell
Worker brood (n = 33 colonies)	296	513	1.73
Drone brood (n = 21 colonies)	365	1323	3.62

The distribution of developed mites found in the emergent worker and drone cells is presented in Figure 4.6. and demonstrates vividly the extent to which mite reproduction fails in Cape honeybees. In 58.4% of emergent worker cells and 27.4% of infested drone cells, infested by one or more varroa mites, there is only one adult mite present, indicating a failure of reproduction in that cell.

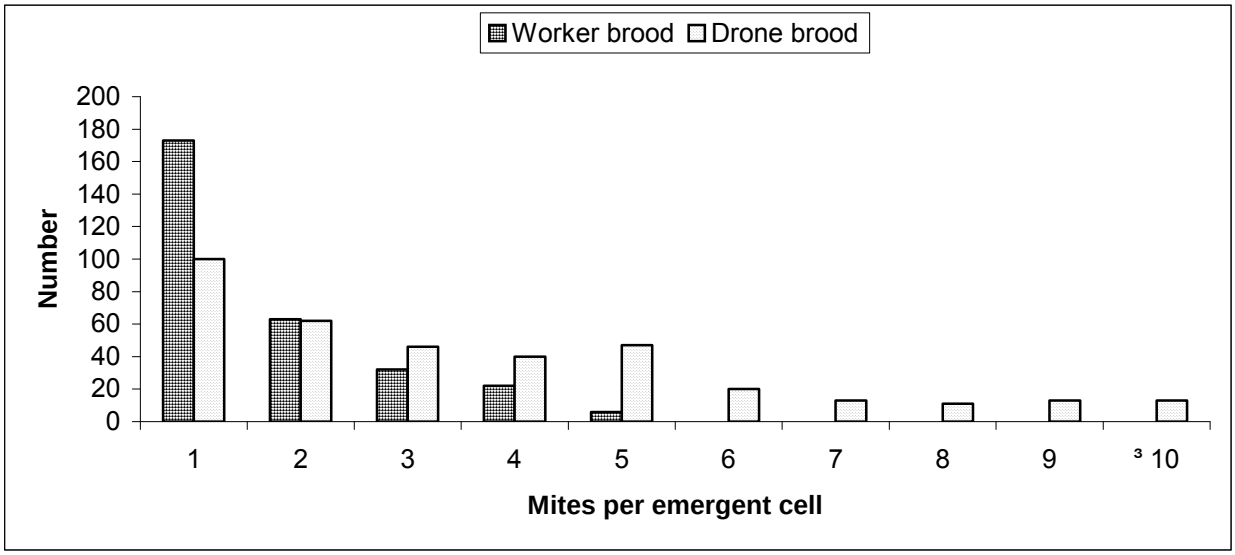


Figure 4.6: Distribution of adult female mites found in emergent drone and worker brood cells in Cape honeybee colonies.

DISCUSSION

Varroa mite (*Varroa destructor*) population growth is generally exponential when the mite population is low (Fries *et al* 1994; Kraus & Page 1995a; Harbo 1996; Harbo & Harris 1999) and differences in growth rates within a population develop over time (Lodesani *et al* 2002; Harris *et al* 2003). Although it is likely that genetically less virulent mite populations will develop at a slower growth rate (Anderson 1994; Anderson & Fuchs 1998; Anderson 2000), climate and hence host colony population dynamics is the major determinant of varroa population growth. In cold climates, mite population growth is expected to be about 10x (or 1000%) per year, and colonies are expected to collapse within 3-4 years (Ritter 1984; Liebig *et al* 1984; Fries *et al* 1991; Korpela *et al* 1992). This corresponds with real population data collected by Calatayud & Verdu (1995) and It would take about 1200 days in northern Europe for the mite population to reach 20 000 in the Calis (2001) model. In warmer climates, such as California, annual mite increases are expected to be between 900% and 2200% with at least 50 dead mites per colony per week after 4 months (Kraus & Page 1995a). Starting from a population of 10 mites (equivalent to this study as probably only 50% of the introduced 20 mites would survive and reproduce), the population models of Calis (2001) would predict 20 000 mites in neotropical colonies by day 250, and for the colonies to succumb within a

year. This is supported by field data from Spain and California (Garcia-Fernadež *et al* 1995; Kraus & Page 1995b). The major cause of variability between the different climatic zones is the availability of brood during the year.

Other major determinants of varroa mite reproductive rates are the percentage and duration of drone brood in colonies and the percentage of reproducing mites (Martin 1995a; Harris *et al* 2003). All models of mite population growth rely very heavily on reproduction in drone cells (Martin 1995a) and this is likely to be even more the case in African bees. Correspondingly, mite populations would be expected to increase in spring and summer, largely due the availability of drone cells (Fuchs 1990; Martin 1995a). However, as mites complete 2-3 reproductive cycles on average (Martin & Kemp 1997) and not the one as originally supposed, there is not so great a dependence on reproduction in drone brood as was suggested to be the case in early varroa population models (e.g. Fries *et al* 1994).

During the monitoring of varroa mite population dynamics in Cape (*Apis mellifera capensis*) and Savanna honeybees (*Apis mellifera scutellata*), it is unfortunate that a number of colonies in both cases were lost, to vandals and the Capensis Problem (Allsopp 1993) in Kwazulu-Natal and to starvation in the Western Cape. Nonetheless, there are enough colonies in both populations monitored for definitive conclusions to be reached. Neither population of honeybees was visibly affected by the presence of varroa mites and colony viability remained relatively constant (Appendix 4; Figures 4.1 & 4.2). The typical pattern for varroa mites is seen in the *A.m. scutellata* colonies, with a very gradual and then exponential increase after about 250 days, reaching a daily mite fall of more than 50 mites per colony per day after 350 days (Appendix 4; Figure 4.4). In contrast, there is the apparent development of tolerance in *A.m. capensis* where the mite population increases very slowly until about 130 days, and then decreases to practically nothing (Appendix 4; Figure 4.3). After fourteen months the mite fall in the Cape colonies is less than 1 mite per week and there is only an average of 113 mites per colony present after 14 months. A total of 2416 mites were recovered after the acaracide treatment of the three surviving *A.m. scutellata* 3 colonies at the end of the monitoring period, indicating a mite population of 805 mites per colony fourteen months after the first introduction of 20 mites into these colonies, almost an order of magnitude greater than in *A.m. capensis* (Appendix 4). These data suggest a striking difference in the ability of *Varroa destructor* to reproduce in two races of honeybees found in South Africa (Figure 4.5). The data suggest that the mite reproduces easily in *A.m. scutellata*, much as the case in other races of *mellifera*, but that there is some inhibition or control of mite reproduction in Cape honeybees. Furthermore, this control appears to take effect after as little as 4 months of mite infestation, and with the mite population in the colonies at a very low level.

And yet, even though the Savanna colonies showed no indication of the type of decrease in mite fall found in the Stellenbosch Cape colonies, and mite population growth fitted the general exponential model reported for *Varroa destructor* in Europe and the USA (Martin 1998). In *A.m. scutellata,* mite population

growth is still retarded in comparison to that found in other neotropical honeybee populations (Garcia-Fernadež *et al* 1995; Kraus & Page 1995a) and is well short of that predicted by Calis (2001). In European bees, natural mite fall onto bottom boards in colonies 12 months after inoculation should be approximately 1600 mites per month, depending on the stock of bee used (De Guzman *et al* 1996). Instead, varroa mite population growth in *A.m.scutellata* in South Africa, in true sub-tropical conditions, is very similar to that of European bees under temperate climates (Calis 2001). This suggests that the tolerance in Cape bees, or whatever causes the failure in varroa mite population growth, might be incomplete or still developing in Savanna honeybees.

Moritz & Mautz (1990) also report a "much reduced mite population growth" in Cape bees when compared to European bees (*Apis mellifera carnica*), and ascribe this to the short post-capping period and the active grooming of Cape bees. However, their data is far from convincing. Although numbers of mites on worker bee samples and in worker brood cells are always greater in *A.m. carnica* than in *A.m. capensis*, most differences are not significant. Tellingly, mite fall data for the two races does not indicate differences. In addition, it must be noted that they monitored colonies for only 4 months and from a variable base, insufficient time to draw any conclusions. And lastly, they kept *A.m. carnica* and *A.m capensis* colonies together in the apiary, which results in the "Capensis Problem" in Germany (Koeniger & Wurkner 1992) just as it does in South Africa (Allsopp 1993). Hence, the *A.m. carnica* colonies would have been influenced by the presence of the Cape bees, and data collected from these colonies should be considered as compromised. The current data set confirms the reduced mite growth in Cape bees, however, and indicates a much greater reduction than reported by Moritz & Mautz (1990).

In contrast to the varroa population dynamics in Savanna and Cape bees which are very different from what was expected and what has been reported for other races of honeybee, brood infestation rates for Cape honeybees are very similar to those reported from elsewhere (Beetsma & Zonneveld 1992; Fries *et al* 1994; Martin 1994; Martin 1995a; Martin 1997b; Calis 2001). 6.2% of worker cells and 25.3% of drone cells are varroa-infested (Table 4.1), comparable to that reported for both Africanized honeybees and for European honeybees (Marcangeli *et al* 1992; Medina & Martin 1999; Carrido *et al* 2003). Surprisingly, brood infestation rates in worker cells do not change much from summer to winter (Table 4.2), unlike those of 20% in autumn and 11% in spring found by Marcangeli *et al* (1992).

Brood infestation rates vary dramatically, between 0% and 50% in worker brood and 0% and 75% in drone brood (Table 4.1), reflecting the arbitrariness of brood infestation data (Fuchs 1990; Boot *et al* 1994b; Boot *et al* 1995a; Martin & Kemp 1997) but also that there is likely to be considerable potential for selection based on brood infestation rates. Efforts to eradicate these limitations, such as studying brood infestation rates in unnatural colonies with set ratios of worker and drone brood, have their own concerns. The extent of varroa infestation in Cape honeybee colonies is found to be significantly correlated with both the worker brood infestation rate and the drone brood infestation rate (Tables 4.3 & 4.4), but as was found

by Fuchs (1990), does not influence the brood infestation ratio. The total amount of brood in the colony, however, does not correlate with worker brood infestation rates, drone brood infestation rates or the brood infestation ratio, in contrast to the results of Fuchs (1990). Finally, and in complete contrast to results with European bees (Fuchs 1990), the percentage of drone brood present does not result in an increase in the brood infestation rate or in the brood infestation ratio. Rather, an increase in the percentage of drone brood in Cape honeybee colonies results in a decrease in worker brood infestation rate (as might be expected), but also in a decrease in drone brood infestation rate (Table 4.4). This suggests that Cape bees produce more drone brood than the varroa mites in the colonies can infest, that the "boom" period of drone production in Cape honeybees results in large numbers of drones being un-infested and healthy, and that Cape honeybee colonies might be able to tolerate very large numbers of varroa mites without colony collapse, and more importantly, without population collapse.

As with brood infestation rates, efforts to calculate *Varroa destructor* reproductive rates are fraught with difficulties and inaccuracies. The method that has generally been used has been to insert mites into brood cells, and then to re-open the cells immediately prior to the emergence of the adult bee, and record the mite offspring in the cell. This method always presupposes that the introduced mite is ready to reproduce, and also requires introduced foundresses to begin reproduction some hours after foundresses that invaded cells naturally. In this study, the artificial introduction of mites into cells was not used. Rather, input mites (that is, the number of mature mites in brood cells just after capping; Table 4.1)) was subtracted from output mites (mature mites in emergent cells; Table 4.5) to determine the reproductive rate of varroa in Cape honeybees. A total of 513 mites (either brick-red or tan, but always fully developed and considered to be adult female mites) were found in the 296 worker cells, or 1.73 mites per emergent worker cell, and 1323 mites were found in the 365 drone cells, or 3.62 mites per emergent drone cell (Table 4.5). Assuming only one foundress per cell, and no death of the foundresses in the cells, this represents the production of 0.73 mature female mite offspring per worker brood cell and 2.62 mature female mite offspring per drone cell. The brood infestation rate data for Cape honeybees (Table 4.1), however, indicates that 20.7% and 48% of foundress mites in worker brood and drone brood respectively were multiple foundresses, reducing the actual reproductive rate in worker brood cells in this Cape honeybee population to 0.38 adult female mites produced per foundress in worker cells and 0.88 adult female mites produced per foundress in drone cells. By way of comparison, Calis (2001) found viable daughters per invaded mite in *A.m. capensis* to be 0.86, as compared to 0.99 for *A.m. carnica/A.m. capensis* hybrids and 1.27 for *A.m. carnica* worker cells. Results are comparable to the "at least 1 viable offspring" found in 40% of infected worker cells in Africanized honeybees by Medina and Martin (1999). This decrease in mite reproduction in Cape bees reflects the development of natural tolerance in the South African population. In contrast, the *A.m. capensis* used by Calis (2001) reflect Cape bees at first exposure to varroa mites, perhaps what would have been the case in South Africa in 1998 rather than in 2000. It would be instructive to repeat the assessment now, as varroa reproductive rates in Cape bees

have probably decreased still further. Moritz & Hänel (1984) report that only 21% of the mites in Cape worker cells are able to successfully reproduce, and this figure might potentially be reduced even more.

The distribution of developed mites found in the emergent worker and drone cells is presented in Figure 4.6 and demonstrates the extent to which mite reproduction fails in Cape honeybees. In 58.4% of emergent worker cells infested by one or more varroa mites, there is only one adult mite present, indicating a failure of reproduction in that cell. This failure could be due to mite infertility, the suppression of mite reproduction, or the shortened post-capping period of Cape honeybees resulting in there being insufficient time for mature female mite offspring to develop in Cape honeybee worker cells. As 27.4% of infested drone cells also have only one adult mite present, and the post-capping period in drone cells is always sufficient for mature females to be produced, some degree of mite infertility or reproductive suppression is clearly indicated in Cape honeybees. This aspect, as well as other possible components to Cape honeybee tolerance to varroa mites, is more thoroughly examined in Chapter 5.

CHAPTER 5

TOLERANCE TO VARROA MITES IN CAPE HONEYBEES

INTRODUCTION

Varroa mite infestations result in the decline and collapse of honeybee colonies, due to effects on development, the shortened lifespan caused to parasitized brood (De Jong *et al* 1982; Schneider & Drescher 1987), and to the mite acting as a vector for other pathogens (Ball 1985). The near-global spread of the varroa mite (*Varroa destructor*) and the catastrophic impact of the mite on honeybee populations in most parts of the world has resulted in the development of a wide range of pesticides to control the mites, particularly pyrethroids and organophosphates, or biotechnical methods to keep colonies alive (Calis *et al* 1997). The rapid and worldwide development of tolerance to these pesticides by varroa mite populations (Watkins 1996; Milani 1999) and the build-up of varroacide residues in bee products (Wallner 1999), has led to a global trend in seeking alternative forms of varroa control (Imdorf *et al* 1996). These efforts have focused on developing Integrated Pest Management strategies (Calderone 1999), on using pesticides generally considered to be less damaging to the environment, on finding a natural enemy or biocontrol agent for the mite, and in the development of mite tolerance in honeybee strains or populations. Integrated Pest Management strategies focus on combining known methods in the most optimal manner, particularly the use of biotechnical control measures, and ensuring that pesticides are utilized at optimal dosages and frequency.

The relationship between *Varroa destructor* and its natural host, *A.cerana,* seems to be balanced with this species of bee being highly tolerant of the mite in comparison to *A. mellifera*. The tolerance in *cerana* results from seasonally occurring drone brood (Tewarson 1987; Rath 1991) which restricts mite reproduction to worker cells for the most part (Koeniger *et al* 1981; Tewarson *et al* 1992; Boot *et al* 1997), the specific cell structure of drone cell caps that promotes the removal of parasitized drones (Rath 1992), and the highly effective grooming behaviour of *A. cerana* workers (Peng *et al* 1987; Rath 1991). A high percentage of the mites found in *A.cerana* worker brood are infertile (Koeniger *et al* 1981), and varroa infested cells are also systematically removed by *cerana* workers (Peng *et al* 1987; Rath & Drescher 1990; Boot *et al* 1997). Such behavioural adaptations confer a high degree of tolerance to varroa mites on *A. cerana*, a tolerance that is not generally apparent in *A. mellifera*. The search for similar varroa tolerance in *A. mellifera* has focused on behavioural factors such as grooming and hygienic behaviour, and life history factors such as short post-capping periods or differential brood attraction (Boecking & Ritter 1994; Büchler 1994). Selective breeding has then been used in an attempt to increase the frequency of traits that confer tolerance.

There is substantial evidence that the impact of varroa mites varies greatly among the different races and populations of *Apis mellifera*, and that some of these populations are in fact relatively tolerant to the mite (De Guzman *et al* 1996). Africanized honeybees are the major example and populations in South, Central and North America have all demonstrated degrees of varroa mite tolerance and survive seemingly suffering little or no ill effects, without the use of chemical treatments (Ritter & De Jong 1984; De Jong *et al* 1984; Ruttner *et al* 1984; Camazine 1986; Engels *et al* 1986; Ruttner 1991; Moretto *et al* 1991; Rosenkranz & Engels 1994; Moretto *et al* 1995; De Jong 1997; Medina 1998; Erickson *et al* 1998; but see Page 1998). Honeybee populations in North Africa (*Apis mellifera intermissa*) also survive without assistance (Ritter 1990; Ducos de Lahitte *et al* 1998), and there are reports that the Cape honeybee (*A.m. capensis*) from South Africa is also likely to be varroa tolerant (Moritz & Hänel 1984; Moritz & Mautz 1990; Moritz & Jordan 1992). Other than African honeybees, there are some reports of populations and strains of European honeybee that are also varroa tolerant. These include European strains in Uruguay (Ruttner *et al* 1984), Austria (Ruttner 1991) and Brazil (Moretto *et al* 1991; De Jong & Soares 1997). Even if populations are not fully resistant to *Varroa destructor*, the impact of the mite varies greatly. Differences in varroa infestation rates and impact occur even in the European races of *A. mellifera*, under standardized conditions, with as much as seven-fold variation in mite infestation levels between strains within one year (Büchler 1990; Otten 1991; Büchler 1994).

African honeybees, or other races, might be tolerant to varroa mites for any of many reasons or traits, or more likely, because of a combination of a number of characteristics. The development time of worker brood has long been considered a key determinant of mite reproductive success (Moritz & Hänel 1984; Moritz 1985; Camazine 1986; Moritz and Mautz 1990), as it limits the development time available for immature mites, potentially preventing them from being successfully mated and reaching adulthood (Ifantidis 1983; Martin 1994). The time needed for the complete development of the first female mite offspring is approximately 230 hours (Ifantidis 1983). In European bees 94%, 38% and 14% of 1st, 2nd, 3rd daughters respectively reach the adult stage (Martin 1994), demonstrating the crucial nature of the length of the post-capping period of worker brood development. While it is apparent that the post-capping period of African bees (particularly Cape honeybees) is very significantly shorter than that of all other races of *Apis mellifera*, there is surprisingly little data to illustrate the situation. The post-capping time of *A.m scutellata* is given as 10-11 days (Smith 1960; Fletcher 1978) and 281 hours (Martin & Kryger 2002). *A.m. capensis* post-capping time has been reported as 10-11 days by Hepburn & Radloff (1998), 252 hours by Calis (2001), 255 hours by Martin & Kryger (2002), 262 hours by Beekman *et al* (2000), 264 hours by Moritz & Jordan (1992), and as little as 9.7 days (233 hours) by Moritz and Hänel (1984). The post-capping period of European bees has been recorded as 12 days (Jay 1962), 279 hours (Vandame *et al* 1999), 282 hours (Martin 1994), 284 hours (Calis 2001) and 286 hours (Siuda & Wilde 2000), generally sufficient for three female mites to reach adulthood (Martin 1994; Calis 2001). Africanized bees are reported to have a post-capping period of 275 hours (Rosenkranz & Engels 1994) to 278 hours (Vandame 1996). Calis *et al* (1996) and

Siuda & Wilde (2000) report that *A.m. carnica / A.m.capensis* hybrids have a development time of about 281 hours and 276 hours respectively.

The shorter developmental time exhibited by African races appears to result in a larger degree of infertility in adult mite females after the invasion of worker brood (Camazine 1986; Ritter & De Jong 1984; Ritter *et al* 1990; Rosenkranz & Stürmer 1992; Rosenkranz & Engels 1994; Aumeier *et al* 1996; but not Kirch & Rosenkranz 1998) or injured or immature male mites (Martin *et al* 1997; Harris & Harbo 1999), thereby keeping the number of mites below the danger threshold and contributing to the relative tolerance of the African honeybee races (Moritz & Hänel 1984). Only the first female offspring is expected to reach adulthood in worker brood of Cape honeybees (Calis 2001) resulting in the mite only being able to reproduce effectively in drone brood, which have a post-capping period of about 14 days (Rehm & Ritter 1989), and which limits the population growth of the mite. In its original habitat, and with its original host (the Asian honeybee, which exhibits an extremely short developmental period), the varroa mite has a balanced parasite-host relationship and does not cause any great damage. Büchler & Drescher (1990) showed that a 8.7% lower mite population growth resulted from a one hour decrease in post-capping period in European bees and a reduction from 12 to 11 days results in a 50% decrease in mite offspring produced [Langenbach, cited in Calis (2001)]. As the heritability of brood development time is high (Moritz 1985), this has long been held as an important characteristic in breeding tolerance to varroa mites.

A second behavioural characteristic that has received a great deal of attention is the hygienic behaviour of different strains and populations of honeybee (Boecking & Drescher 1998; Spivak & Reuter 1998; Boecking & Spivak 1999; Corrêa-Marques & De Jong 1998). Hygienic behaviour, a specific response of bees to diseased and parasitized brood, is said to be the primary natural defence against diseases and pests, typically American Foulbrood and chalkbrood (Rothenbuhler 1964; Gilliam *et al*1983). Hygienic bees detect, uncap and remove diseased bees, and would result in the removal of varroa mites from infested brood cells (Peng *et al* 1987; Rath & Drescher 1990; Spivak & Reuter 1998; Corrêa-Marques & De Jong 1998). Most early studies on varroa tolerant bees focussed on the general hygienic behaviour of bees. Hygienic behaviour has often been ill-defined, sort of a general “clean-up” response. It has commonly been measured by ability and speed of colony to remove brood that has been killed by pins or by freezing. Typically, a 2-inch piece of sealed brood (about 100 brood cells) is removed and frozen or pin-killed (Spivak & Gilliam 1998; Spivak & Downey 1998) and then returned to the colony to see how long it takes for the cells to be uncapped and the dead brood removed. If cells are cleaned out within 48 hours, the bees are generally considered as hygienic (Taber 1982; Spivak & Downer 1998; Spivak 1996).

Colonies, strains, races and species of bees are highly variable as regards their hygienic behaviour and the characteristic is highly heritable (Boecking & Drescher 1991; Boecking & Drescher 1992; Spivak 1996; Spivak & Reuter 1998). In *Apis cerana* the varroa mite reproduces only in male brood as most infested worker cells are detected by worker bees and eliminated from the hive (Peng *et al* 1987;

Rath 1991; Tewarson *et al* 1992; Boecking 1999). African and Africanized bees are generally regarded as having better hygienic behaviour than European bees (Moretto *et al* 1991; Loper 1995; Corrêa-Marques & De Jong 1998; Guerra *et al* 2000). Fries & Raina (2003) report that 77% of pin-killed brood is removed by *Apis mellifera scutellata* in 24 hours, a removal rate considerably higher than previously reported for Africanized bees (Danka & Villa 1994; Loper 1995) and much higher than for European bees (Spivak 1996; Spivak & Reuter 1998). *A.m. intermissa* have also been reported to be very hygienic (Kefuss 1995). Others have not found a difference in the hygienic responses of Africanized and European bees (Aumeier *et al* 1996; Aumeier & Rosenkranz 2001).

A general albeit often weak negative correlation has been found between the efficacy of brood removal and susceptibility to varroa mites (Büchler 1992; but not Arechavaleta-Velasco & Guzmán-Novoa 2001; Lodesani *et al* 2002). At best, colonies with better hygienic responses survived longer than those without, but all died out in the end (Spivak & Reuter 2001). Almost all studies report great colony variability in hygienic response (Lodesani *et al* 2002; Fries & Raina 2003); hence, the potential for breeding programmes (Spivak & Reuter 1998). A more direct method to investigate hygienic behaviour with respect to varroa mites is the artificial infestation of brood. A slight cut is made in a cell cap and a mite is inserted (Boecking & Ritter 1993). Mites may also be introduced with a Jenter queen-rearing kit (Spivak 1996) or with the half-comb method (Boot *et al* 1992; Beetsma *et al* 1993). Cells are monitored to determine if the cell has been opened and the mite and/or infested brood have been removed. Mite removal seems not to be determined by chemical cues provided by the mite (Aumeier & Rosenkranz 2001) but it is affected by the number of mites present in the cell (Boecking & Ritter 1993; Spivak 1996; Calis 2001; Flores *et al* 2001). Once again there is a great deal of variability in mite removal. Spivak (1996) found that 5-28% of infested cells were removed, Boecking & Ritter (1993) found 38% removal, and Boecking & Drescher (1991) found 5-96%. African bees remain more hygienic than European bees. Calis (2001) found that Cape honeybee colonies opened and cleaned 26% of cells invaded by one mite, compared to only 5% of cells for *Apis mellifera carnica*. In cells invaded by more than one mite, 20-30% of cells were opened for both races. Finally, Vandame (1996) reports from Mexico that European bees removed only 8% of infested brood while Africanized bees removed 32.5% of infested brood.

A further behavioural characteristic long associated with varroa tolerance, and prominent in selective breeding strategies, is that of direct aggression by worker honeybees to phoretic mites by grooming. The infested bee tries to remove the mite by licking and biting, and by vigorous movements of the mesothoracic legs (Peng *et al* 1987). Asian bees engage in mutual grooming and can entirely remove mites from a colony (Peng *et al* 1987; Büchler *et al* 1992) and it has been suggested that mite tolerance in a number of *Apis mellifera* populations is due to their ability to remove mites through grooming [*A.m.intermissa* (Boecking & Ritter 1993); *A.m.capensis* (Moritz & Mautz 1990); *A.m.carnica* (Ruttner & Hänel 1992); *A.m.ligustica* (Lodesani *et al* 1996)]. In contrast to hygienic behaviour, grooming is an interaction between adult bees. The general method of investigation is to collect fallen mites on a hive insert and to check for damaged mites. *Damage* levels of 30-50% are common

(Bienefeld *et al* 1999). The typical damage caused to mites through successful grooming are injuries to the legs and dorsal shields of the mites (Rosenkranz *et al* 1997) caused by the biting and chewing of adult bees (Thakur *et al* 1997), although it should be borne in mind that mites can also get damaged in brood cells or by hive pests and predators, especially waxmoth larvae. Moosbeckhofer (1992), Rosenkranz *et al* (1997) and Ruttner & Hänel (1992) report 37%, 45% and 30-50% respectively of fallen mites as being damaged by bites, and all report a negative correlation with infection levels as have other studies (Büchler 1993; Arechavaleta-Velasco & Guzmán-Novoa 2001). Other studies have reported less damage to fallen mites. Vandame *et al* (2002) report 10% mutilated mites in European honeybee colonies and 15% mutilated mites in Africanized colonies, both in Mexico. Yet other studies report damage being caused to fallen mites, as much as 37% mutilation, but no correlation between grooming and mite infestation levels (Fries *et al* 1996; Harbo & Harris 1999; Corrêa-Marques *et al* 2000; Lodesani *et al* 2002).

In general it is held that African or Africanized bees are better groomers than are European bees (Moretto *et al* 1991; Delfinado-Baker *et al* 1992; Moretto *et al* 1993; Guzman-Novoa *et al* 1999; Aumier 2001). The active defence of the African bees is recorded to be similar to that of the natural host *Apis cerana* (Peng *et al* 1987), defence that is largely absent in European races of *Apis mellifera* (Ruttner & Hänel 1992). It is important to record, however, that grooming need not necessarily mutilate the mites (Büchler *et al* 1992; Thakur *et al* 1997; Aumier 2001), but might simply cause the mites to be removed from a bee, later to re-attach. Hence, high grooming rates need not have any significant effect on mite population levels. In addition, all such studies rely on the examination of dead mites recovered from screened bottom boards fitted to honeybee colonies, and damage to mites on these bottom boards could easily be caused by other predators or scavengers such as ants, waxmoth larvae or pseudoscorpions.

Another characteristic that needs consideration in a study of varroa tolerance is the attraction to brood by the varroa mites. As the volatile substances in the larval cuticle are probably responsible for the recognition of an appropriate host larvae by the mite (Le Conte *et al* 1989), it is possible that these substances are reduced or different in some strains of honeybee, reducing infection rates and hence mite population growth and the impact of the mites. Guzman-Novoa *et al* (1996) and Vandame (1996) reported that the infection rate in Africanized bees was 2-6 times lower than that of European bees and suggested a reduced attractiveness of the brood of Africanized bees to varroa mites. Camazine (1986) and Aumeier & Rosenkranz (1997), however, did not find this reduced attractiveness and could not determine race-specific volatile signals originating from larvae. Büchler (1989) found that *A.m. mellifera* larvae are less attractive than either *A.m. carnica* or Buckfast bees, but in general, few differences in terms of mite attraction have been found between races of honeybee (Calis *et al* 1997; Calis 2001; DeGrandi-Hoffman *et al* 2002). Arechavaleta-Velasco & Guzmán-Novoa (2001) and DeGrandi-Hoffman *et al* (2002) also found no correlation between brood attraction and mite infestation levels.

The observation that large numbers of infertile mites were present in honeybee populations tolerant to varroa has led to mite infertility becoming perhaps the most widely invoked explanation for varroa tolerance (Harbo & Hoopingarner 1997). Wherever there have been varroa-tolerant bees in the world, there has always been a high proportion of non-reproducing mites found in worker brood cells (Ruttner *et al* 1984; Ritter 1990; Eguares *et al* 1995), although some authors report no correlation between mite infertility and levels of varroa infestation (Kirsch & Rosenkranz 1999; Arechavaleta-Velasco & Guzmán-Novoa 2001; Lodesani *et al* 2002).

It has frequently been suggested that mite infertility is particularly prominent in African or Africanized bees and that this is the reason for varroa tolerance in these bees (Ritter & De Jong 1984; Camazine 1986; Engels *et al* 1986; Rosenkranz *et al* 1990; Rosenkranz & Engels 1994; Martin *et al* 1997; Medina & Martin 1999). Others have found no difference in mite infertility between Africanized and European bees (Guzman-Novoa *et al* 1996; Vandame *et al* 2000). The extent to which infertile mites have been found, however, suggests that the characteristic is not limited to Africanized bees, but is perhaps more pronounced in Africanized bees. While the 19-25% infertile mites in European bees and 43-53% infertile mites in Africanized bees in Brazil, Mexico and Europe (Ritter & De Jong 1984; Camazine 1986; Rosenkranz & Engels 1994; Guzman-Novoa *et al* 1996; Guzman-Novoa *et al* 1999; Medina & Martin 1999; Aumeier *et al* 1999; Rosenkranz 1999; Lodesani *et al* 2002) suggest a population-based difference, the 28-42% infertile mites on European bees in Argentina (Marcangeli *et al* 1992) and 70-90% infertile mites on European bees in Uruguay (Ruttner *et al* 1984) suggest that race is not a factor. Some twenty to fifty percent of mites in colonies of *A.m. intermissa* in Tunisia are infertile (Ritter 1990).

While mite infertility has been demonstrated to have seasonal effects (Otten & Fuchs 1990; Marcangeli *et al* 1992; Kulinčević *et al* 1988) and it can be influenced by the age of bees in the colony (Büchler 1994), it is primarily due to some genetic characteristic of the bees (and not the mites) (De Ruitjer 1987; Boot *et al* 1995) and is highly heritable (Harbo & Harris 1999). Normally 10-15% of mites do not lay eggs (Rosenkranz & Bartalszky 1996; Harris & Harbo 1999). Selecting from honeybee colonies in the USA, and selecting only for this characteristic (= the percentage of non-reproducing varroa mites in worker brood cells), the percentage of reproducing mites was reduced to as low as 6% (Harbo & Harris 2001), and later to 3% (Harbo and Harris 2005) after many generations of selection (Harbo 1996; Harbo & Hoopingarner 1997; Harris & Harbo 2000). Mite infertility has also been called SMR (Suppressed Mite Reproduction), indicating colonies that had few reproductive mites in the worker brood. The characteristic was found to be conferred by the queen (Harris & Harbo 2000; Harbo & Harris 2001) and consequently SMR colonies and queens were widely distributed to beekeepers in the USA, these colonies being referred to as varroa mite tolerant.

There are four main explanations for mite infertility. (1) The mother mite may not lay eggs in the brood cell, or oviposition may be delayed. Normally a foundress mite lays the first egg about 70 hours after cell capping and each additional egg at 30 hour intervals (Steiner *et al* 1994). Juvenile hormone or

some other signal has been suggested to delay or prevent mite oviposition (Garrido *et al* 2000; Anderson 2002; Garrido & Rosenkranz 2003). (2) The foundress may produce only male eggs (Donzé *et al* 1996; Martin *et al* 1997) or no eggs at all. This would result from the mite being unmated. Harris & Harbo (1999) report that mites that did not lay eggs had fewer spermatozoa than normally reproductive mites, and that half of the infertile mites had no spermatozoa at all in their seminal vesicles. (3) Mothers or males may be being killed in the cells, perhaps because of smaller cell size, which in the latter instance would result in daughter mites not being mated and an unmated mite population (Fries *et al* 1994; Martin 1994; Martin 1995a; Donzé *et al* 1996; Martin *et al* 1997; Medina & Martin 1999; Martin & Kryger 2002). Martin & Kryger (2002) have suggested that the extra-feeding received by *A.m. capensis* worker bees in *A.m. scutellata* colonies (Allsopp *et al* 2003) results in less space and more mother mite mortality. (4) The post-capping period might be too short, preventing sufficient mating of daughter mites from being completed (Harris & Harbo 1999), as daughter mites must mature sufficiently to be repeatedly mated by their brothers before the cell is uncapped. Sperm transfer only occurs in matings taking six minutes or more, and mature female offspring require frequent re-mating to be fully mated (Donzé *et al* 1996). This will result in a gradual increase in non-reproducing mites as the initially reproductive mites are lost.

In its widest sense, mite infertility or “non-reproducing mites” should be defined as any foundress mite that fails to produce a viable female offspring from a worker cell. This can be due any of the following: (a) the foundress dying in the cell prior to reproduction; (b) the foundress not producing any eggs; (c) the female offspring not being able to mature sufficiently by the time the worker bee emerges; and (d) the male dying in the cell preventing the female offspring being mated. All possible classifications have been used by various authors (e.g. Fries *et al* 1994; Martin 1994; Martin 1995a; Donzé *et al* 1996; Calis *et al* 1999b) and a great deal has been made of male loss or male death by some authors (Martin *et al* 1997; Medina & Martin 1999). The most sensible approach is that of Harbo & Harris (2005), who use as a working definition that non-reproductive mites are those that fail to produce a single mature female offspring, for whatever reason, irrespective of the presence of male offspring.

A final behavioural characteristic, the possibility that worker cell size was responsible for the observed tolerance in Africanized and African honeybees caused great excitement in beekeeping circles with beekeepers in Europe, USA and New Zealand producing African-bee sized foundation on which to keep their bees. African worker cells are approximately 4.7mm in diameter, compared with 5.1mm for European bees. The idea was that these African cells did not have enough room for varroa mites to reproduce, and originated with Message & Concalves (1995) who reported lower varroa reproduction and lower varroa infestation in the smaller Africanized cells. Medina & Martin (1999) also found increased varroa offspring mortality in worker cells of Africanized bees, compared to European bees, and suggested this was because of the reduced cell size of African bees. However, none of the early studies separated cell size with other African (or Africanized) characteristics, such as a shorter post-capping period. More recent studies (e.g Taylor 2005), using only European bees but with different cell

sizes, has shown that smaller cells do not limit mite infestation or mite reproduction, and that smaller cells might actually increase varroa infestation rates.

Bearing in mind the range of characteristics that might confer varroa tolerance to honeybee populations, there have been two general strategies to further develop or identify these characteristics and populations. Some efforts have monitored the characters believed to confer tolerance such as grooming behaviour, brood attraction, hygienic behaviour and mite fertility, and tried to correlate these characteristics with varroa infestation levels in colonies (e.g. Kulinčević *et al* 1988; Harbo & Hoopingarner 1997; Spivak & Reuter 1998; Spivak & Gilliam 1998; Harbo & Harris 1999; Arechavaleta-Velasco & Guzmán-Novoa 2001; Lodesani *et al* 2002). Selective breeding, the choosing of queens with desirable characteristics to mate with drones from colonies with desirable characteristics (Harbo & Harris 2001), is then used to try to further develop the mite tolerance (Büchler 1994). In principle, any character with a correlation to reduced colony susceptibility to varroa mites may be useful in a breeding programme. Characteristics chosen have included brood infestation rates (Kulinčević *et al* 1988), post-capping period (Wilde & Koeniger 1992, cited in Büchler 1994), damaged mites (Wallner 1993, cited in Büchler 1994) and varroa population growth (Büchler 1993b). The general methodology used in this strategy is to select a number of honeybee colonies on the basis of some characteristic presumed to confer varroa tolerance, apply a fixed number of mites to each colony, wait one to two years, and try to correlate survivorship with the selected characteristic (e.g. Berg *et al* 2001). Predictably, the time period is commonly not long enough and the selection criteria not broad enough, and these studies seldom produce positive results.

An alternative strategy is to simply allow a wild or managed honeybee population to be subjected to varroa mite damage, without any intervention or chemical treatment, and then to breed from the "varroa-tolerant" survivors, the "live and let die" strategy (Fries 2001). There is only one absolutely clear and well publicised case where bees have survived indefinitely without treatment, and that is the Africanized bees in Brazil (Ruttner 1988; De Jong 1996). There are, however, many other reported cases, which together illustrate a general phenomenon of honeybee population survivorship. Monaco (1997), for example, found that the swarming rates of colonies in Italy had recovered 10-12 years after first exposure to varroa mites. These survivor strains have been extensively developed and marketed in the USA, particularly the "Yugo" bees (Kulinčević *et al* 1992; Rinderer *et al* 1993) and the "Russian" bees (Rinderer *et al* 2001). These stocks represent the survivors of early *Apis mellifera* populations to be exposed to varroa mites, in the 1880's in the case of the Russian bees (Crane 1978). The "live-and-let-die" approach has been widely tried [Austria (Ruttner 1991); Turkey (Çakmak *et al* 2003); Italy (Monaco 1997); Arizona (Erickson *et al* 1998, 1999)] and reflects the situation in Brazil (De Jong *et al* 1984; Moretto *et al* 1991; Moretto *et al* 1995; De Jong & Soares 1997) and other parts of South and Central America (Rosenkranz 1999), but perhaps nowhere as extensively as is the case in South Africa. Honeybee colonies from natural, unmolested populations have been trapped in more than a dozen nature reserves across South Africa (Chapter 2) and monitored for mite population growth and for mite impact. These colonies were established with no maintenance or assistance being given for

the duration of the monitoring period. Populations were monitored for a period of five years, to determine the effect of varroa mite infestations on natural, wild honeybee populations, and to monitor for the possible development of mite tolerance in these populations.

It is also possible that it is not only are the race of honeybee and its behavioural attributes that are important in predicting the outcome of honeybee-mite interactions, but also what viruses and other pathogens are present in the honeybee population (Ball 1997; Bowen-Walker *et al* 1998). There is considerable evidence that colonies infected with varroa eventually collapse as a result of secondary infections, and of these, viruses activated by the presence of the mites are most important. This would imply that a key factor for the development of mite tolerance in a honeybee population is the relative absence of secondary pathogens in that population.

Another consideration is the suggestion that it is the type of mite present that dictates the level of tolerance in a honeybee population, and not attributes of the honeybee population. Of the two mite haplotypes that are able to reproduce successfully on *Apis mellifera*, one (Japanese-type) is relatively non-virulent and the other (Korean-type) is extremely virulent (De Guzman *et al* 1998; Anderson & Fuchs 1998; Anderson 2000). In only three places in the world (prior to South Africa) has varroa not caused massive colony losses, these being Japan, Russia and Brazil, and these are the only places where the Japanese-haplotype has been found. Elsewhere varroa has caused massive colony losses, and in all cases the Korean-haplotype is present. Hence, the alternative explanation is that it was not the bees that were tolerant to varroa mites, but rather than the mites were not virulent. This explanation is supported by reports that not only Africanized bees in South America but also European bees were untroubled by varroa (Ruttner *et al* 1984; Moretto *et al* 1991; De Jong & Soares 1997) and also by reports that Africanized bees in the USA and central America that have been recently exposed to the Korean-type mite are collapsing due to the mite (Erickson *et al* 1998; Page 1998; Medina 1998). As it is the Korean-type varroa mite that is present in South Africa (Anderson & Trueman 2000), this alternative suggestion would predict massive colony mortality due to the varroa mite, comparable to that found in most parts of the world, irrespective of the behavioural attributes African bees might possess.

Additional to the range of characteristics that may determine relative tolerance to varroa, it is apparent that *Varroa* infestations are also influenced by environmental (De Jong *et al* 1984; Moretto *et al* 1991) and seasonal (Marcangeli *et al* 1992) conditions, and even by the pollen levels in colonies (Janmaat & Winston 2000). It might be expected that varroa mites are at their most devastating in tropical areas where brood is available throughout the year (De Jong *et al* 1984) but this has not been the case. Typically, no control measures have been necessary in tropical regions (De Jong *et al* 1984; De Jong 1996) and the mite appears to be most effective under cooler, temperate conditions (Ritter & De Jong 1984; Ritter *et al* 1984; Ruttner *et al* 1984; Engels *et al* 1986; Woyke 1987; Moretto *et al* 1991; Garcia-Fernàndez *et al* 1995). Conditions in South Africa are more tropical than temperate, and mite population levels may be expected to remain below dangerous levels. The situation in the Cape, a

region with a more temperate climate, might well be more serious. The mite has proved to be extraordinarily virulent in California (Finley *et al* 1996), much of which has climatic conditions very similar to the Cape.

In addition to attempting to develop varroa-tolerant bee strains, considerable effort has been placed in trying to locate or develop biocontrol strategies for varroa mites. In the thirty years that the varroa mite has been an international pest, no successful natural enemies of the mite have been discovered. Predatory mites, parasitoids and entomopathogens have been considered (Chandler *et al* 2001) of which entomopathogenic fungi appear to be the most likely candidates (Shaw *et al* 2002). None of the fungi found naturally on varroa mites appear to be effective biocontrol agents (Benoit *et al* 2004) and although non-specific entomopathogenic fungi can be introduced to colonies to control the mites (Kanga *et al* 2003) there are substantial delivery problems (Chandler *et al.* 2001) and no immediate prospects of varroa biocontrol. The 1999 announcement by a number of beekeepers from the central regions of South Africa that varroa mites in their colonies were being controlled by pseudoscorpions or "bee scorpions" therefore aroused considerable interest in world beekeeping circles (Donovan & Paul 2005). Bee scorpions belong to the genus *Ellingsenius* Chamberlin, of which there are eight species described from southern, central and eastern Africa as well as India, and are restricted to the nests of bees or associated with honeybees (Singh & Venkatraman 1947; Subbiah *et al.* 1957; Murthy & Venkataramanan 1985; Murthy & Venkataramanan 1986; Judson 1990; Sudarsanam & Murthy 1990; Dippenaar-Schoeman & Harvey 2000). Of these, two species are known from South Africa (Dippenaar-Schoeman & Harvey 2000): *E. fulleri* (Dunbrody) and *E. sculpturatus.* These pseudoscorpions live along with the bees in hives and both adults and juveniles are found clinging on to the adult worker bees. They feed on small, sluggish micro-arthropod fauna found in the beehives, which include different species of mites, larvae of moths and other insects (Singh & Venkatraman 1947; Murthy & Venkataramanan 1985; Judson 1990; Sudarsanam & Murthy 1990).

The tolerance of commercial and wild Cape honeybee colonies to the Korean-type haplotype of *Varroa destructor* under essentially tropical conditions was evaluated and monitored, and the various factors that might confer tolerance (grooming, short post-capping period, hygienic behaviour, mite infertility, brood attraction and biocontrol by pseudoscorpions) was investigated.

METHODS & MATERIALS

Tolerance in Wild honeybee populations

An unmanaged population of honeybees has been maintained in the Cape Point section of the Table Mountain National Park (formerly the Cape of Good Hope Nature Reserve) since 1991. This site was specifically chosen as it is removed from all commercial beekeeping, removed from any influence of bees of the race *Apis mellifera scutellata*, and free of any exotic bee-friendly forage (Allsopp &

Hepburn 1997). The original objectives were to study the basic biology and reproduction of the Cape honeybee under natural condition. Cape honeybees are presumed to have evolved on the Cape peninsula (Guy 1976). The population of honeybees in the reserve is considered to be as pure *Apis mellifera capensis* as exists anywhere, and in natural vegetation typical of that occupied by this race of bee prior to advent of commercial beekeeping.

The colonies in the reserve were trapped in the reserve, transferred to standard Langstroth hives and maintained in one of two apiaries within the reserve. Colonies were monitored on a regular basis for colony strength, brood and pollen stores and reproductive events (Allsopp & Hepburn 1997). No management was applied to colonies and apart from the monitoring, colonies fully represent the wild population of the reserve. The hives were maintained with minimal interference; no beekeeping takes place with these colonies and they were simply observed. Hive bodies were periodically emptied by a colony dying, or re-colonized by a new honeybee swarm moving in. Surplus empty hive bodies were always available at the two apiary sites.

After the first detection of the varroa mite in the Cape in August 1997, the existing colonies at Cape Point were thereafter regularly monitored for the presence of the mite. All colonies were sampled 3-4 times a year from August 1997 until June 2004. The adult worker population in each colony was estimated as the number of gaps between top bars visibly filled with bees (Allsopp & Hepburn 1997). Each frame was examined for brood and stored pollen and a determination was made of the number of frames of brood and pollen in the colonies. The number of cells with visible chalkbrood was counted in each colony, as an indication of the presence of the varroa mite. A sample of approximately 300 worker bees was collected from the brood nest of each colony. The sample was analysed for varroa mites by means of the hot-water method Chaper 2). The number of adult bees in the sample was also counted and the varroa load (mites per 100 adult bees) determined.

Tolerance in commercial honeybee populations

After the initial collapse of honeybee colonies soon after exposure to varroa mite (Table 3.1; Appendix II), it soon became evident that commercial colonies of the Cape honeybee were tolerant of the mite to varying degrees. This was apparent in the sampling of colonies during surveys conducted for the mite (Appendix I) and especially during the comprehensive monitoring of commercial colonies for the impact of the mite (Appendix III). In an effort to assess the possible development of varroa tolerance in the commercial honeybees in the Cape, and as a comparison to the monitoring of varroa mites in wild honeybee populations, repeat sampling of commercial apiaries belonging to three beekeepers were carried out.

Three commercial apiaries that were sampled in early 1998 and showed significant varroa infestation were selected for repeat sampling. The beekeepers owning the apiaries agreed not to treat the colonies in each apiary, and to keep each apiary as a discrete unit without adding new colonies to the site or removing colonies from the site. Other than that the colonies were treated as normal

commercial colonies by the beekeepers, used for commercial honey production and migrated for commercial pollination. All colonies in the three apiary sites were sampled for varroa mites 5-6 times between early 1998 and early 2002. A sample of approximately 300 adult bees was removed from the brood nest of each colony and analysed for varroa mites using the hot water method (Chapter 2).

Potential factors affecting tolerance to *Varroa destructor* in Cape honeybees

1. **Hygienic behaviour & Varroa Removal**

Three commercial beekeepers in the Western Cape donated their "best" colonies, the colonies that they considered had shown least negative effects resulting from varroa infestation, for this study. A total of 20 colonies were collected from these beekeepers, and these colonies were moved into a single isolated apiary site near Grabouw in early 1999. All colonies were maintained in standard 10-frame Langstroth boxes with queen excluders, and where given honey supers as necessary. The colonies were treated as normal commercial colonies in that surplus honey was removed when available, and the colonies were used for the commercial pollination of pears and apples in Elgin in August/September 1999 and 2000.

All colonies were monitored regularly for hygienic response and varroa load (mites per 100 worker bees from the brood nest). Hygienic behaviour was assessed by using liquid nitrogen application to the sealed brood in the field. A 3-inch (diameter) piece of hard plastic tubing (plumbers piping) was sharpened on one side so that it could cut into the brood comb. When twisted into the comb down to the level of the wax foundation, it formed a seal into which approximately 100ml of liquid nitrogen was added. The liquid nitrogen was then allowed to evaporate, a process which took about five minutes, and the brood frame would then be returned to the colony. After 24 hours these frames were removed from the colonies, and the number of cells circumscribed by the tubing mark that had been opened and the brood removed was counted. The total number of cells in this area was 164 cells.

All colonies were assessed on seven occasions between March 1999 and December 2000, at which stage the experiment was terminated as insufficient colonies remained alive. On each occasion basic data was collected from all colonies (frames of bees, frames of brood, queen-state), using standard methods (Allsopp & Hepburn 1997), a frame of sealed brood was removed and given the liquid nitrogen treatment testing for hygienic behaviour, and a sample of bees was removed from the brood nest for later screening for varroa mites by the hot-water method (Chapter 2). When no sealed brood was present in the colonies, hygienic response for that colony could not be determined. When too few worker bees were present (in colonies in terminal decline), no worker sample was taken for varroa analysis).

Data were analysed using the programme Statistical Analysis System (SAS), version 8.2, 1999. Pearson's Product Moment Correlation Coefficients ($p \leq 0.05$) was used to test the relationship between hygienic behaviour and varroa population level. As with the monitoring of the Cape

commercial honeybee population (Chapter 3) and the investigation of the relationship between the varroa mite and the Capensis Problem (Chapter 3), an effort was made to determine whether either hygienic behaviour or varroa mite levels in these colonies were predictive of their imminent demise. For each sampling period colonies were divided into two groups: (a) alive in the subsequent sampling period and (b) dead in the subsequent sampling period. A Students t-test for Least Significant Difference (LSD) was the parametric test performed to test whether the difference between groups was greater than would be expected by chance (P = 0.05).

The direct removal of varroa mites from infested brood cells was assessed in 2002 using the half-comb method (Boot *et al* 1992; Beetsma *et al* 1993; Boot *et al* 1994). For each of two combs, the bottom of the cells were removed and replaced with a transparency. These two half-combs were then fixed together, back-to-back, in a single frame and placed in colonies of *Apis mellifera capensis* with low varroa numbers (less than 1.2 mites per 100 bees) until eggs were laid in the frames (donor colonies). These frames were then transferred into recipient colonies which had relatively high varroa numbers (greater than 6.5 mites per 100 bees). Frames were monitored daily, and when the first cells were sealed the frames were removed and checked. The half-combs were detached, and the base of the cells checked for varroa mites. Cells were marked with typex if one varroa mite was in the cell. There were insufficient cells with more than one varroa per brood cell for these to be assessed. The half-combs were then re-joined, and the frame returned to their original colony, now the discriminator colony. After 8 days the frame was removed, and the marked cells were opened to determine if the mite remained in the cell or had been removed (empty cell), and if successful mite reproduction had taken place. Direct varroa removal was assessed in 3 Cape colonies, on two separate occasions for each colony.

2. Aggression towards mites

Standard varroa screens (Chapter 4) were placed below 6 colonies in Stellenbosch in September 1998, and all fallen mites were collected daily for a period of six days. Varroa screens were processed daily to lessen the chance that injuries to the mites on the screens would be caused by hive scavengers and not by bees. All mites, both alive and dead, were collected. Colonies were placed on stands, with the legs of the stands smeared with Plantex (UAP – South Africa) to prevent access of ants into the colonies. Predator and scavenger-proof hives are necessary to ensure that any damage to the mites is caused by the honeybees or normal hive scavengers (Bienefeld *et al* 1999). All collected mites were carefully accessed for bite marks or missing limbs using a Leitz microscope at 80X magnification.

3. Attractiveness of brood

The relative attractiveness of *A. m. scutellata* and *A.m. capensis* brood to varroa mites was examined using the methodology of Büchler (1989) and Calis (2001). Frames of open brood of both races were placed into varroa-infected colonies of *A. m. scutellata* and *A.m. capensis*, as well as into hybrid colonies of the two races. Six hybrid colonies from Leeu-Gamka (Allsopp *et al* 2003) were used as

recipient colonies, together with 3 *A.m.scutellata* colonies from Kenhardt and five *A.m.capensis* colonies from Stellenbosch. The three groups of colonies were kept in separate apiaries to prevent *A.m.capensis* infiltration of the *A.m.scutellata* or hybrid colonies (Allsopp 1993). A fourth *A.m.scutellata* colony and a sixth *A.m.capensis* colony, from Kenhardt and Stellenbosch respectively, were used as donor colonies.

Frames of open brood (larvae) were removed from the two donor colonies. Pieces of brood with large larvae (1-2 days before capping) were cut from these frames, typically of approximately 100 worker brood cells per piece but occasionally substantially larger. One piece of *A. m. scutellata* brood and one piece of *A.m. capensis* brood were then inserted into an empty (but drawn) brood frame, holes cut into it to accommodate the pieces of brood (Allsopp *et al* 2003). Each frame was then inserted into a recipient colony, between two frames of open brood. Just prior to the brood emerging, the donor frames were removed from the colonies and each sealed cell was carefully opened and examined. The presence or absence of varroa mites in the cells was recorded, as was successful reproduction of those mites that were present.

Data were analysed using the programme Statistical Analysis System (SAS), version 8.2, 1999. A Students t-test for Least Significant Difference (LSD) was the parametric test performed to test whether the difference between groups was greater than would be expected by chance (P = 0.05), both of the infestation of the two types of brood by varroa mites (brood attractivity) and the success of reproduction of the mites in the two types of brood cells.

4. Mite Fertility and Reproductive Fate

Frames of brood were removed from colonies of the Cape honeybee in Stellenbosch during both the summer and winter months of 1999 and 2000 to determine the relative attraction of worker and drone brood cells to varroa mites in Cape honeybees, and the levels of infestation in the two types of brood (Chapter 4). A sample of worker bees was collected from the brood nest from each of these colonies and the varroa load in each colony determined by sieving and counting mites and bees by the hot-water method (Chapter 2). All colonies had low or medium levels of *Varroa destructor* infestation, and none of the colonies had ever been treated with varroacides (Chapter 4). These same frames of brood were now examined to determine the reproductive fate of varroa mites in both worker and drone cells.

Worker and drone brood cells in which the occupant was a fully developed bee (worker or drone), and about to emerge, were used. These were brood cells in which the mite reproductive cycle was considered to be complete, and were used to determine the mite reproductive fate for the two types of brood cells. The worker or drone in the opened cell had to be fully developed and moving, to be included in the data set. A total of 200 worker cells and a total of 200 drone cells at this stage of development, or as many of each as were available in each colony, were carefully open with a scalpel and forceps and the larva or pupa in the cell removed. The number and type of varroa mites on the larva or pupa was carefully counted. Each empty cell was carefully examined with a Fibre Optic

Illuminator and any mites remaining in the cells were removed and counted. In previous studies of the reproductive fate of *Varroa destructor* in brood cells (Donzé *et al* 1996; Medina & Martin 1999; Martin & Kryger 2002), an effort was made to determine the fate of the male offspring in the cell. The cells could be classified into six categories (Martin & Kryger 2002): (1) mother dead; (2) mother only; (3) only male offspring; (4) mature and mated female offspring; (5) unmated female offspring because of male mortality; and (6) immature female offspring only. In this study, the fate of the male offspring was found to be difficult to determine. If the male dies early in development, often all that remains is a tiny white fleck which can be very hard to find (Martin pers. comm.). In this study, therefore, only four categories were used: (1) mother dead; (2) no offspring, male or female; (3) mature females (either mated or unmated) produced, indicated by adult exuviae found in the cell (Donzé *et al* 1996), and by other immature stages of female brood; and (4) only immature females produced, indicated by the absence of exuviae in the cell. Note that mother mites may be readily identified from their offspring, on the basis of colour and the hardness of the cuticle (Medina & Martin 1999; Martin per comm.). Young adults are paler, often tan in colour, and the cuticle is soft and pliable. In the characterization of Harbo and Harris (2005), only category (3) would qualify as successful reproduction. Brood at the appropriate stage (emergent brood) was found in 33 of the colonies examined, for worker brood, and 21 colonies for drone brood.

5. Post-capping period in *Apis mellifera capensis*

The data on the post-capping period in African bees, including *Apis mellifera capensis*, is considered to be fragmentary, and this parameter needed to be more accurately measured so that its role in varroa tolerance could be assessed. Fourteen Cape honeybee colonies were used in this study, six during winter and eight during summer, as temperature in the colony was considered to potentially be important in terms of brood development time. The method used was that of Martin (1995). In all cases a frame of brood was removed from a colony, and all sealed worker brood cells marked with white Typex. The frame was then returned to the colony, and then removed again after two hours. All unmarked sealed worker brood cells were now marked with green typex and the frame returned to the colony. Between 11 and 60 cells were marked for each of the fourteen colonies. The second time that the frames were returned to the colonies, after the cells had been marked green, was considered as the beginning of the post-capping period for recording purposes. After a further nine days and 17 hours (233 hours) the frame was removed from the colony, all green-marked cells counted and recorded on a transparency, and the colony placed in an incubator at 32ºC. The frame was removed every two hours and checked for emergence of worker bees from the green marked cells until all bees had emerged. Bees that did not emerge at all from the marked cells were not included in the data.

6. Biocontrol by pseudoscorpions

The beekeepers that reported pseudoscorpions as controlling varroa mites in their colonies were visited, and their honeybee colonies inspected for pseudoscorpions. In addition, more than 400 honeybee colonies of other beekeepers in various parts of the country were inspected for the presence of pseudoscorpions. Colonies were inspected for the presence and abundance of

pseudoscorpions in Gauteng, Western Cape, Eastern Cape, North West and Kwazulu-Natal provinces.

RESULTS

Tolerance in Wild honeybee populations

The varroa population levels in the natural Cape Point honeybee population are indicated in Table 5.1 and Figure 5.1. The first varroa mites in the population were found in October 1998, and mite infestation of colonies slowly increased until January 2001 when 88% of colonies were mite infested. The mite population levels also rose consistently during the period, to peak at a population maximum of 6.44 mites per 100 bees in January 2001. Thereafter, both the mite population levels and the numbers of colonies testing positive for varroa steadily declined, with the population level reaching 0.61 per 100 bees in March 2002 (Table 5.1; Figure 5.1). Mite population levels at Cape Point have remained below 1 mite per 100 bees since early 2002 and have even declined further, with only 0.06 mites per 100 bees found in June 2004. During the entire time period (1998 to 2004) honeybee colony vitality (measured in terms of frames of bees and brood production) was stable (Figure 5.1), although fluctuating with seasons, and no negative impact of varroa mite infestation could be discerned. The presence of chalkbrood in the colonies did mirror the development of the mite population (Table 5.1; Figure 5.1) but never developed to damaging levels.

As no honeybee colonies have been seen to succumb to varroa mites during this period, and certainly the honeybee population has not collapsed, it can only be concluded that the Cape Point honeybee population is now totally tolerant to the varroa mite, that this tolerance developed without any substantial colony losses, and that the tolerance developed within four years. This is the first time that mite population levels have been continuously recorded in a honeybee population from the first arrival of the mites until the honeybee population could be concluded to be totally mite tolerant.

Tolerance in commercial honeybee populations

The results of the repeated sampling of commercial colonies for varroa mites are presented in Appendix I, in the 1998 Surveys, 1999 Surveys and 2000-2002 Surveys sections. Samples taken from apiaries for repeat sampling are indicated as K1-K5, L1-L5 and P1-P6. The results of this repeat sampling are presented in Table 5.2 and Figure 5.3. Colony numbers in apiaries belonging to Nico Langenhoven and to ARC-PPRI decrease as colonies die or abscond, and are not replaced. Colony numbers in the apiary owned by Rolf Kriebel fluctuate as empty trap-boxes are maintained in the apiary to catch honeybee swarms. As queens in colonies were not marked, it is impossible to be certain that the colony being monitored was the same the colony monitored on the previous occasion. However, the arrival of fresh colonies is considered to be a minor contributor to the apiary, and colonies sampled during each inspection are likely to be those that had survived since the previous inspection.

Table 5.1: Monitoring of colonies of *Apis mellifera capensis* for varroa mites in the Cape Point honeybee population between 1997 and 2004.

Date	Number of colonies	Average number of frames of bees in colonies	Average number of frames of brood in colonies	Number of colonies with varroa*	Number of colonies with >20 cells of chalkbrood	Population varroa load **
August 1997	14	7.60	4.20	0	0	0.00 (0 in 4189)
October 1997	14	6.80	3.75	0	0	0.00 (0 in 4982)
March 1998	14	5.95	1.80	0	0	0.00 (0 in 4033)
October 1998	14	9.52	4.54	1	0	0.03 (1 in 3993)
January 1999	13	6.75	1.20	7	0	0.60 (22 in 3665)
March 1999	13	5.52	1.78	8	0	0.64 (25 in 3876)
July 1999	11	7.26	2.38	8	0	1.17 (38 in 3255)
January 2000	21	6.88	2.60	14	0	1.39 (91 in 6532)
August 2000	22	8.66	3.75	13	0	1.04 (67 in 6443)
October 2000***	20	8.40	4.60	16	1	3.82 (195 in 5104)
January 2001***	17	6.55	2.03	15	8	6.44 (322 in 5001)
June 2001	13	7.60	3.70	9	6	1.28 (55 in 4284)
November 2001	12	8.45	4.05	9	9	2.53 (107 in 4237)
March 2002	12	6.30	2.34	6	2	0.61 (23 in 3765)
May 2002	12	8.65	2.74	3	1	0.21 (8 in 3897)
July 2002	12	9.40	4.16	2	3	0.04 (2 in 4685)
September 2002***	11	8.90	3.81	0	4	0.00 (0 in 3802)
December 2002	8	8.63	3.75	3	3	0.28 (7 in 2494)
April 2003	9	7.10	2.05	2	3	0.11 (4 in 3506)
October 2003	14	9.35	4.78	3	1	0.08 (4 in 4965)
June 2004	19	8.75	5.05	2	2	0.06 (4 in 6821)

* Number of colonies with varroa found in a sample of 300 worker bees collected from the brood nest.

** A sample of approximately 300 worker bees was collected from the brood nest of each colony. Mites were separated from the sample using the hot-water method and counted. All worker bees in the samples were counted. The numbers of mites and number of bees in each sample were summed to determine a population varroa load (mites per 100 bees).

*** Two colonies were removed from the monitored population on each occasion, for other experiments.

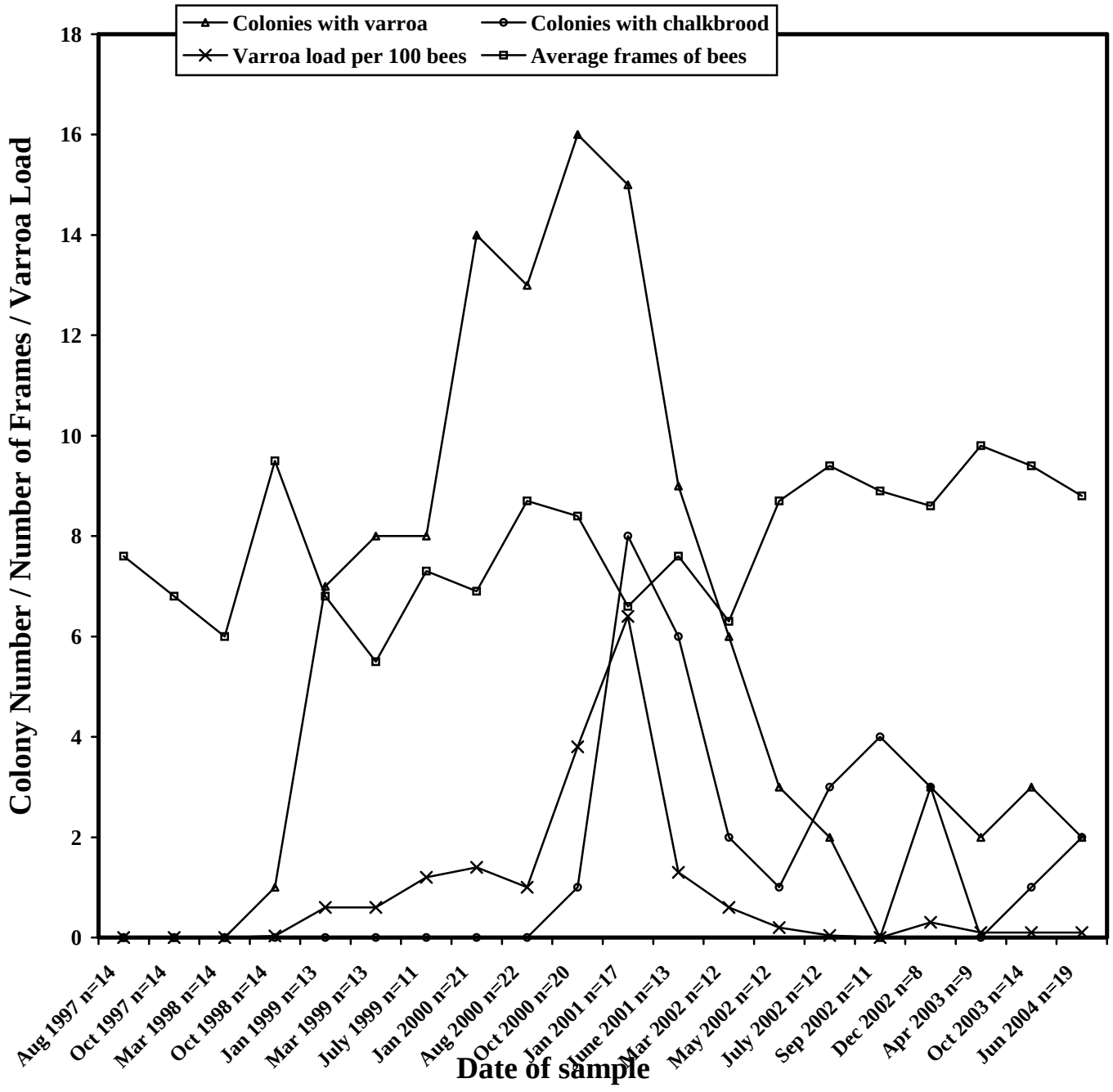


Figure 5.1: Varroa monitoring of a Cape Point honeybee population between 1997 and 2004.

In all three apiaries the varroa population can be seen to increase and then decrease over time (Table 5.2; Figure 5.2), indicating the development of varroa tolerance in the honeybee colonies. Furthermore, only relatively small numbers of honeybee colonies were lost during the monitoring period. Only 15 colonies or 34% of colonies were lost in the Paarl and Elsenburg apiaries over the entire monitoring period, and it is highly unlikely that all these losses could be ascribed to varroa infestation. Nonetheless, this figure of 34% puts an upper limit on colony losses that might be expected in a commercial Cape honeybee population before varroa mite tolerance was developed.

Table 5.2: Development of varroa tolerance in commercial honeybee colonies of the Cape honeybee (1998-2002).

Beekeeper	Apiary site	Sample identification	Date	Colonies in apiary	Varroa Range*	Average varroa load in apiary**
Rolf Kriebel	Philadelphia	K1	15/02/98	31	0-107	21.68 ± 24.38
		K2	04/11/98	37	5-325	94.14 ± 63.85
		K3	17/12/99	32	6-67	23.94 ± 15.21
		K4	17/01/01	30	0-32	9.13 ± 8.54
		K5	08/02/02	33	0-25	5.31 ± 5.90
Nico Langenhoven	Paarl	L1	27/2/98	24	0-12	3.08 ± 3.40
		L2	25/1/99	22	1-29	9.55 ± 7.97
		L3	15/12/99	22	3-43	18.64 ± 12.03
		L4	22/01/01	16	0-22	6.38 ± 5.81
		L5	15/02/02	14	0-16	4.36 ± 5.46
ARC-PPRI	Elsenburg	P1	16/02/98	20	0-27	4.85 ± 6.27
		P2	02/02/99	20	1-27	12.55 ± 9.04
		P3	15/12/99	19	3-32	11.47 ± 7.37
		P4	20/06/00	19	1-92	12.79 ± 22.20
		P5	11/01/01	17	0-44	6.47 ± 11.20
		P6	04/02/02	15	0-13	2.67 ± 3.72

* Number of varroa found in a sample of 300 worker bees collected from the brood nest.

** A sample of approximately 300 worker bees was collected from the brood nest of each colony and mites separated using the hot-water method. Mites and worker bees in the sample are counted to produce a varroa load (mites per 100 bees).

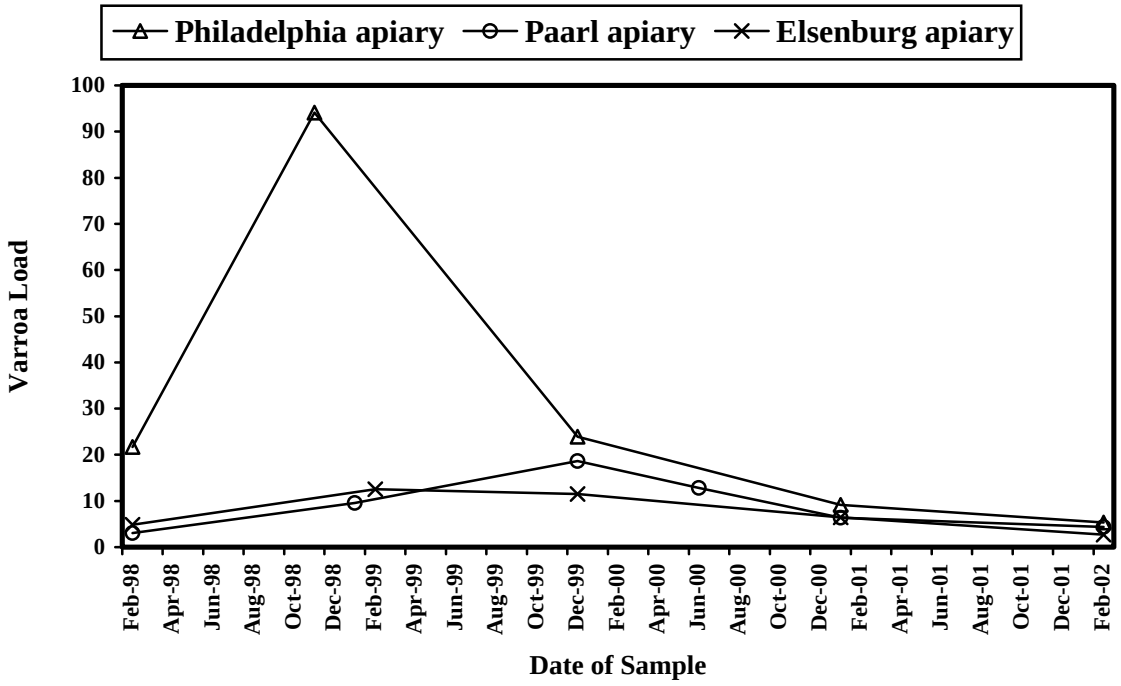


Figure 5.2: Change in varroa load (mites/100 bees) in commercial honeybee colonies of the Cape honeybee (1998-2002).

Potential factors affecting tolerance to *Varroa destructor* in Cape honeybees

1. Hygienic behaviour & Varroa Removal

Hygienic behaviour, measured by scoring the percentage of freeze-killed brood that was removed within 24 hours, was found to be highly variable over time and also between colonies (Table 5.3; Figure 5.3). Hygienic behaviour in Cape honeybees as measured by the percent removal of dead bees, was found to vary between 26% and 58%. The population varroa load in these colonies increased during the first year of the monitoring period, and then decreased during the second year (Table 5.3; Figure 5.3). Only ten colonies remained alive in December 2000 when the monitoring was terminated.

There was no correlation between hygienic behaviour and varroa load over the monitoring period (Pearson Correlation coefficient; r = -0.09684; p = 0.3234; n = 106). The relationship between hygienic behaviour and varroa load to the "alive" and "dead" groups was assessed using a Students t-test for Least Significant Difference (LSD), to test whether the difference between groups was greater than would be expected by chance (P = 0.05). The hygienic behavioural data was normally distributed (Shapiro-Wilk p = 0.957) but the varroa data was non-normal and remained non-normal even after efforts to transform it {logit transformation; Snedecor & Cochran (1967)}. The data is symmetrical, however, and results remain valid when using the original data and using a Students t-test. Results are indicated in Table 5.4. Hygienic behaviour was found to be strongly predictive of colony mortality, with those colonies with the poorest hygiene succumbing first. Varroa load is not predictive of colony mortality (Table 5.4).

Table 5.3. The percentage of dead bees removed from cells (hygienic behaviour) and varroa population levels of twenty Cape honeybee colonies monitored between March 1999 and December 2000.

		Hygienic behaviour (%)	Varroa mites per 100 bees
March 1999 N=20	Mean	57.9	1.1
	Std. Dev	24.3	1.6
May 1999 N=20	Mean	39.0	2.8
	Std. Dev	28.1	2.9
August 1999 N=20	Mean	36.2	4.1
	Std. Dev	20.0	3.7
December 1999 N=17	Mean	51.4	4.3
	Std. Dev	31.0	4.2
April 2000 N=15	Mean	29.8	3.0
	Std. Dev	21.7	1.0
June 2000 N=13	Mean	25.8	1.3
	Std. Dev	12.7	0.8
December 2000 N=10	Mean	26.9	1.2
	Std. Dev	26.5	0.7

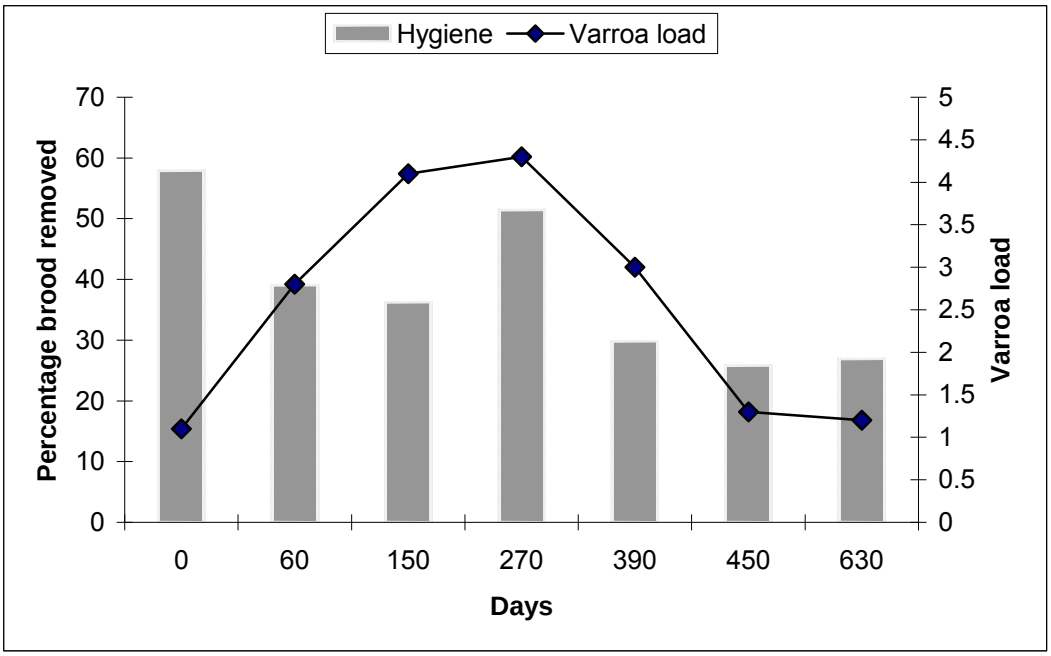


Figure 5.3. The relationship between hygienic behaviour measured by the percentage removal of dead brood and varroa population levels measured as number of mites/100 bees in twenty Cape honeybee colonies monitored between March 1999 and December 2000.

Table 5.4. The hygienic behaviour and varroa population levels of twenty Cape honeybee colonies monitored between March 1999 and December 2000. Data is analysed using a Students t-test (Least Significant Difference, $p \leq 0.05$). Means with the same letter are not significantly different.

Dependent Variable = Hygienic behaviour					
Colonies	Hygienic Behaviour		n	Grouping	LSD statistic
	Mean	Standard error			
Alive	42.287	2.77	94	a	15.648
Dead	24.750	3.40	12	b	
Dependent Variable = Varroa Load					
Colonies	Varroa mites per 100 bees		n	Grouping	LSD statistic
	Mean	Standard error			
Alive	2.60	0.29	97	a	1.712
Dead	3.42	0.86	13	a	

Hygienic behaviour was also investigated by monitoring the direct removal of varroa-infested worker brood in three *Apis mellifera capensis* colonies, on two occasions for each colony (Table 5.5), using the half-comb method (Boot *et al* 1992; Beetsma *et al* 1993; Boot *et al* 1994). Of the 250 marked worker cells 23 or 9.2% were found to be varroa infested when opened by the worker honeybees of the discriminator colony, and the honeybee pupae and varroa mite in the cell removed. It is significant that the removal rate between colonies varied from 1.9% (colony 132) and 39.5% (colony 108). Most (63.9%) mites that were not detected and removed were able to successfully reproduce, and immature female offspring were present in the cells.

Table 5.5. The direct removal of varroa mites from varroa-infected brood cells in three *A. mellifera capensis* colonies, using the half-comb method. Half-comb frames of eggs from colonies with low varroa loads (donor colonies) were transferred to colonies with high varroa loads (recipient colonies) until the cells were sealed. These frames were then checked for varroa-infected cells and returned to their original colonies (discriminator colonies). After eight days the frames were check to determine if varroa-infested cells had been removed, and if reproduction had been successful in those cells were the mites were still present.

Brood Donor	Recipient Colony	Discriminator colony	Cells Marked	Cells cleared	Successful Reproduction	Unsuccessful Reproduction
165	25	165	64	3	39	22
165	26	165	37	1	27	9
108	25	108	18	11	7	0
108	26	108	25	6	16	3
132	25	132	47	2	21	24
132	26	132	59	0	35	24
Totals			250	23 (9.2%)	145 (63.9%)	82 (36.1%)

2. Aggression towards mites

A total of 2148 fallen mites were examined for bite marks or missing limbs. Only 4 mites (0.19%) were found with definite bite marks, all these being present on dead mites (Table 5.6). None of the 476 live mites recovered from the varroa screens exhibited any bite marks or missing limbs.

Table 5.6 Direct aggression towards varroa mites as indicated by bite marks on mites collected on varroa screens placed inside the bottom boards of 6 colonies in September 1998. Varroa screens were removed and all mites were collected every day for a period of 6 days.

	Number of dead mites collected			Number of Live Mites collected			Total number of mites collected		
	Without bite marks	With bite marks	%	Without bite marks	With bite marks	%	Without bite marks	With bite marks	%
Colony 1	66	0	0.00	32	0	0.00	98	0	0.00
Colony 2	702	2	0.28	209	0	0.00	911	2	0.22
Colony 3	182	0	0.00	68	0	0.00	250	0	0.00
Colony 4	34	1	2.94	23	0	0.00	57	1	1.75
Colony 5	511	1	0.20	101	0	0.00	612	1	0.16
Colony 6	177	0	0.00	43	0	0.00	220	0	0.00
Totals	1672	4	0.24	476	0	0.00	2148	4	0.19

3. Attractiveness of brood

The relative invasion by varroa mites of *Apis mellifera scutellata* and *A.m.capensis* brood in *A.m.scutellata*, *A.m.capensis* and hybrid colonies, and the reproductive success of the mites in these brood cells, is indicated in Table 5.7. Approximately one hundred open brood cells of each honeybee race were placed into each donor colony for mites to invade. Data was assessed using a Students t-

Table 5.7. Varroa infestation rates (brood attraction) and mite reproduction in *A.m scutellata* and *A.m.capensis* brood placed in *A.m scutellata*, *A.m.capensis* and hybrid colonies. A section of *A.m scutellata* and *A.m.capensis* open brood, from one donor colony of each race, is placed into an empty drawn comb that is inserted between brood frames in 6 hybrid, 5 *A.m.capensis* and 3 *A.m.scutellata* colonies. Varroa mite invasion and mite reproduction is determined by examining cells just prior to bee emergence.

Recipient Colony	Varroa Load (mites per 100 bees)	Donor Brood	Varroa-infested cell	Cells without varro mites	Successful reproduction
H1	3.9	*scutellata* LV21	0	100	0
		capensis 158	0	34	0
H2	6.5	*scutellata* LV21	18	82	14
		capensis 158	7	93	6
H3	2.0	*scutellata* LV21	11	96	10
		capensis 158	1	100	1
H4	2.1	*scutellata* LV21	9	54	9
		capensis 158	1	99	1
H5	1.2	*scutellata* LV21	20	93	
		capensis 158	29	148	
H6	1.5	*scutellata* LV21	5	325	
		capensis 158	4	290	
Hybrid Totals	2.9 (mean)	*scutellata* LV21	63	750	33
			8.4%		89.6%
		capensis 158	42	764	8
			5.5%		88.9%
		Total	105	1514	41
			6.9%		89.4%
C1	3.8	*scutellata* LV21	17	83	16
		capensis 158	6	84	5
C2	0.6	*scutellata* LV21	2	69	2
		capensis 158	0	100	0
C3	1.3	*scutellata* LV21	8	92	8
		capensis 158	8	92	8
C4	2.2	*scutellata* LV21	0	83	
		capensis 158	3	195	
C5	2.3	*scutellata* LV21	0	414	
		capensis 158	4	150	
Capensis Totals	2.0 (mean)	*scutellata* LV21	27	741	26
			3.6%		96.3%
		capensis 158	21	621	13
			3.4%		92.9%
		Total	48	1362	39
			3.5%		95.1%
S1	4.2	*scutellata* LV21	8	92	6
		capensis 158	15	85	7
S2	2.6	*scutellata* LV21	11	89	7
		capensis 158	1	99	1
S3	1.7	*scutellata* LV21	1	99	0
		capensis 158	1	99	1
Scutellata Totals	2.8 (mean)	*scutellata* LV21	20	280	13
			7.1%		65%
		capensis 158	17	283	9
			6.0%		52.9%
		Total	37	563	22
			6.6%		59.5%
TOTALS	2.6 (average)	*scutellata* LV21	110	1771	72
			6.2%		84.7%
		capensis 158	80	1668	30
			4.8%		75%
		Total	190	3439	102
			5.5%		81.6%

test for Least Significant Difference (LSD), to test whether there was a difference between brood origin infestation rates and reproductive success greater than would be expected by chance (P = 0.05). Results are indicated in Table 5.8. There is no significant difference between *Apis mellifera scutellata* and *A.m.capensis* brood in terms of varroa infestation rate (= attractivity of the brood) or the reproductive success of the mites that do invade brood cells, for any of the four recipient groups (*A.m. scutellata* colonies, *A.m.capensis* colonies, hybrid colonies, and all colonies combined).

Table 5.8. Varroa infestation rates (brood attraction) and mite reproduction in *A.m scutellata* and *A.m.capensis* brood placed in *A.m scutellata*, *A.m.capensis* and hybrid colonies. Data is analysed using a comparisonwise Students t-test (Least Significant Difference, $p \leq 0.05$). Means with the same letter are not significantly different.

	Recipient Colonies	Brood Type	Mean	Standard Error	t-test grouping	LSD statistic
Varroa mite infestation rate (= brood attraction)	Hybrid	*capensis*	4.46	2.60	a	9.23
		scutellata	10.30	3.23	a	
	capensis	*capensis*	3.76	1.53	a	8.20
		scutellata	5.56	3.21	a	
	scutellata	*capensis*	5.67	4.66	a	15.35
		scutellata	6.67	2.96	a	
	Total	*capensis*	5.02	1.73	a	4.88
		scutellata	9.09	2.26	a	
Varroa mite reproductive success	Hybrid	*capensis*	71.43	24.05	a	81.17
		scutellata	67.17	22.85	a	
	capensis	*capensis*	61.11	30.93	a	86.05
		scutellata	98.04	1.96	a	
	scutellata	*capensis*	82.22	17.78	a	81.46
		scutellata	46.21	23.34	a	
	Total	*capensis*	81.57	10.50	a	37.64
		scutellata	60.15	13.61	a	

4. Mite Infertility & Reproductive Rate

Brood frames were removed from 33 Cape honeybee (*Apis mellifera capensis*) colonies during both the winter and summer months of 1999 and 2000. Recently sealed brood cells were examined to determine varroa mite infestation rates (Chapter 4), and brood cells just prior to the occupant emerging were used to determine the reproductive fate of the varroa mite in the brood cell. A total of 4554 emergent worker cells (from 33 colonies) and 1608 emergent drone cells (from 21 colonies) were examined (Table 5.9). Of the cells from which workers had emerged, 6.5% were occupied by one or more varroa mites while 22.7% of emergent drone cells were similarly occupied. The reproductive fate of varroa mites in both drone and worker cells is indicated in Table 5.9. Very few dead foundress mites are found in brood cells (0.7% and 0.8% for worker and drone brood respectively). In contrast, 26% of mother mites are found alone in the cell, without any offspring, for both worker and drone emergent brood. 35% of mites in worker cells and 2% of mites in drone cells reproduce too late or too slowly for a female offspring to be fully mature when the honeybee occupant emerges from the cell, and 39% of mites in worker cells and 72% of mites in drone cells successfully

produce an adult female offspring (Table 5.9). Put another way, in Cape honeybees 61% of varroa mites in worker brood cells and 28% of varroa mites in drone brood cells are non-reproducing (Harbo & Harris 2005).

Table 5.9: The reproductive fate of varroa mites in worker and drone brood cells of the Cape honeybee, during both winter and summer. Worker brood was examined from 33 colonies and drone brood from 21 colonies. Only emergent brood is used to ensure that the varroa mites in the brood cells have completed their reproduction.

	Worker Brood	**Drone Brood**
Number of colonies	33	21
Number of cells examined	4554	1608
Number of cells with varroa mites(s)	296	365
Percentage of cells that are mite infested	6.5%	22.7%
Mother mite(s) only	76 (25.68%)	94 (25.75%)
Mother mite(s) dead	2 (0.68%)	3 (0.82%)
Mother mite(s) and immature female offspring only	102 (34.46%)	7 (1.92%)
Mother mite(s) and mature female offspring (one or more)	116 (39.19%)	261 (71.51%)
Percentage of non-reproduction	60.81%	28.49%

5. Post-capping period in *Apis mellifera capensis*

Results are presented in Table 5.10 and Figure 5.4. The average post-capping period for worker brood from fourteen Cape honeybee colonies from the Stellenbosch region, measured in both summer in winter, is found to be 263.8 hours. Seventy percent of workers emerged after their cells had been sealed for periods between 259 and 269 hours (Table 5.10). Notably, there is tremendous variation in post-capping time, both within and between colonies, with post-capping times varying from 241 hours to 281 hours. The least variation in colony post-capping period was 10 hours for colony X2, and the greatest was 34 hours for colony 162. It was striking that in many colonies there would be a few workers emerging considerably earlier than the rest of the brood, often with a significant time lag before the next workers emerged (Table 5.11).

6. Biocontrol by pseudoscorpions

A thorough inspection of 432 commercial and “wild” honeybee colonies over a nine-month period, including those of all but one of the beekeepers reporting a pseudoscorpion–varroa link, delivered a total of only 7 colonies with pseudoscorpions (1.6%). In only one colony were more than a few pseudoscorpions present (Table 5.11). No pseudoscorpions were found in the Western Cape, confirming previous sampling records

Table 5.10. The duration of the post-capping period of worker bees in 14 colonies of Cape honeybee (*Apis mellifera capensis*).

Colony	Month	Emergence (bees for each hour)																						Total
		241	243	245	247	249	251	253	255	257	259	261	263	265	267	269	271	273	275	277	279	281	283	
213	Oct		1	1			1				4	2	6	5	6	5		2	1					34
169	Oct										5	1	3	6	5	7	3	1						31
168	Oct										4	5	3	1	6	2		1						22
166	Oct				1	2		2	8	5	11	12	4	5	4	4		1	1					60
162	Nov		1										4	5	6	8	6	7	14	2				53
170	Nov								2	3	3	9	14	4	5	3								43
163	Nov							1	1			2	3	1	6	6	1	2						23
173	Nov			2		3	2	4	2	6	3	10	10	5		3			2					52
X1	June	2	1	4	2	2	1		2	2														16
X2	June										4	1	5	11	3	2								26
20	July						1	2	1	1	5		1	3	1	2	3	2						22
13	July										1			1	5		3		1					11
16	July										1		1		3	7	1			1				14
15	July										1	1	5		5	12	4	2	2	1	1	1		35
Total		2	3	7	3	7	5	9	16	17	42	43	59	47	55	61	21	18	21	4	1	1		442

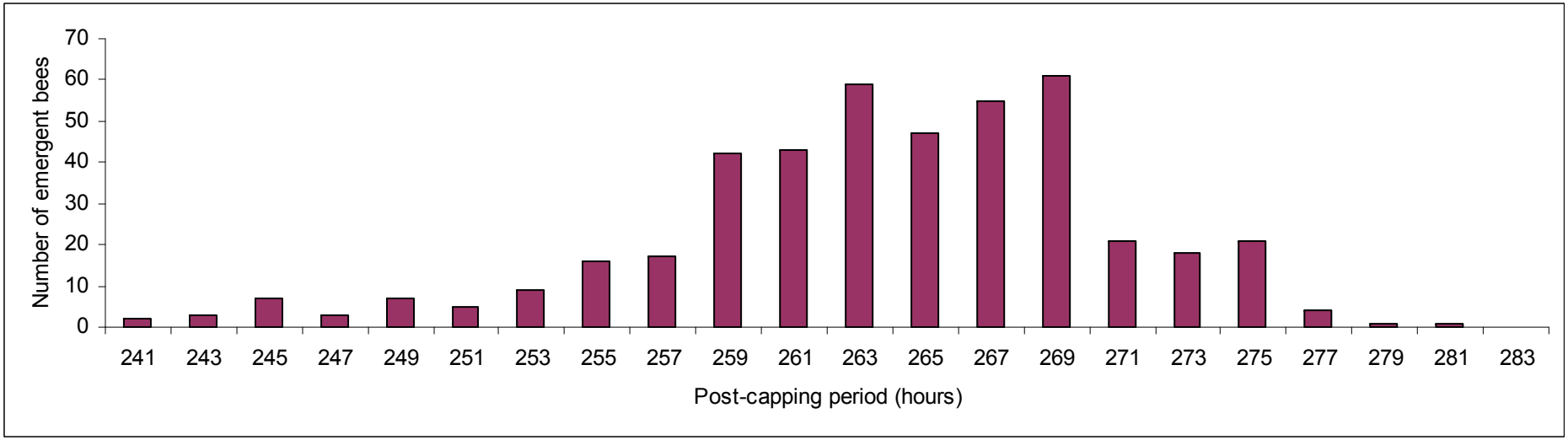


Figure 5.4. The frequency distribution of post-capping periods of workers from of 14 colonies of Cape honeybee (*Apis mellifera capensis*).

Table 5.11: Numbers of pseudoscorpions found in South African honeybee colonies.

Region/Site	Number of colonies sampled	Number of colonies with pseudoscorpions	Total number of pseudoscorpions
Grahamstown 1	9	0	0
Grahamstown 2	11	1	5
Hout Bay	22	0	0
Johannesburg	9	0	0
Leeufontein	17	2	±30
Porterville	27	0	0
Pretoria 1	95	1	1
Pretoria 2	30	0	0
Rayton	20	1	1
Richmond	29	0	0
Rustenburg 1	20	1	1
Rustenburg 2	15	0	0
Settlers	15	1	1
Somerset West	24	0	0
Stellenbosch	69	0	0
Suikerbosrand	20	0	0
TOTALS	**432**	**7**	**39**

DISCUSSION

Since the arrival of the varroa mite in South Africa, the focus has been on the possible impact of the varroa mite on the wild honeybee population, rather than the effect on commercial bees, and on the potential development of tolerance to the mite. This was based on the presumed importance of the wild honeybee population in the pollination of indigenous flora, the importance of wild honeybees in providing honeybee colonies for small-scale, subsistence beekeepers in rural areas, of whom there are many tens of thousands in Africa and the dependence of commercial beekeepers in Africa on replacement of colonies from the wild honeybee population. It was also critical to know how long it would take for varroa tolerance to develop and what degree of population decline would occur. For these reasons, wild honeybees were trapped in nature reserves throughout South Africa, and the impact of varroa on these bees monitored. The seven-year continuous record from one of these reserves, Cape Point, demonstrates that this Cape honeybee (*Apis mellifera capensis)* population has developed almost total tolerance to the varroa mite (*Varroa destructor*), to the extent that there are practically no mites remaining in these colonies (Table 5.1; Figure 5.1). Furthermore, this varroa tolerance developed within 4-5 years of the first arrival of the mite, and without any significant colony losses. Indeed, varroa populations in the Cape Point honeybee population never rose to dangerous levels, peaking at 6.5% after three years. This is the first case of fully-documented mite tolerance anywhere in the world, where a population has been continuously monitored from the first arrival of the mite until full tolerance has developed, and the first accurate confirmation that (at least) some African honeybees are tolerant to the varroa mite. This result is consistent with reports that Africanized honeybees (Ritter & De Jong 1984; De Jong *et al* 1984; Ruttner *et al* 1984; Camazine 1986; Engels *et*

al 1986; Ruttner 1991; Moretto *et al* 1991; Rosenkranz & Engels 1994) and bees from North Africa survive varroa mites without assistance (Ritter 1990; Ducos de Lahitte *et al* 1998), and those that have previously suggested that Cape honeybees would be varroa tolerant (Moritz & Hänel 1984; Moritz & Mautz 1990; Moritz & Jordan 1992).

The more general nature of varroa tolerance in the Cape honeybee population is confirmed by the monitoring of commercial colonies (Table 5.2; Figure 5.2), which also demonstrate the development of varroa tolerance. Even though varroa numbers in these commercial colonies were extremely high, there was relatively little colony loss, and certainly no population collapse. The substantial differences in maximum mite numbers between the commercial colonies (Table 5.2; Appendix I) and the wild, unmanaged colonies (Table 5.1) are puzzling. The tolerance exhibited in the Cape Point population (Table 5.1) occurs with varroa infestation rates far below those reported for other varroa-tolerant populations (Moretto *et al* 1991; Erickson *et al* 1998). Perhaps it was the greater stress placed on the commercial colonies (in chasing honey flows and during commercial pollination) that makes them more susceptible to the mites. Or maybe the high-density apiaries that commercial colonies are kept in (in contrast to the widely dispersed colonies at Cape Point) lend themselves to continuous re-infestation by the mites, and to very high mite numbers. The greater size of commercial colonies, with more brood and with brood for longer, might also contribute to a larger varroa population. Or perhaps it is just that the Cape Point wild population is totally unselected and has a greater genetic diversity, potentially leading to rapid varroa tolerance.

Notwithstanding the greater varroa numbers in commercial colonies during peak infection, the decrease in varroa mites in these colonies illustrated in Table 5.2 has continued, to the extent that varroa mites are now relatively rare in the Cape honeybee population of the Western Cape. The tolerance of *A.m.capensis* to varroa is borne out by the total absence of problems reported by beekeepers in the area since 2003, and by the purchase of commercial varroacides being so poor that all of these products have been de-registered and discontinued in South Africa.

As for the underlying causes of the observed varroa tolerance in Cape honeybees, a number of factors were investigated. Some of these factors clearly were not involved in varroa tolerance in Cape honeybees, these being aggression directed at the mites or grooming by the bees to mechanically remove mites, the relative attractiveness of *A.m.capensis* brood, and the possibility of pseudoscorpions acting as biocontrol agents of the varroa mite. A mere 0.2% (4 out of 2148; Table 5.6) of mites on the hive inserts were found to have bite marks, indicating the almost total lack of direct aggression towards varroa mites by Cape honeybees. The bites on these few mites could well have been received post mortem, probably from organisms such as pseudoscorpions or the small hive beetle. The absence of groomed mites is in marked contrast to the damage levels of 30-50% reported previously from many different honeybee populations, including from *A.m.capensis* (Moritz & Mautz 1990; Ruttner & Hänel 1992; Boecking & Ritter 1993; Rosenkranz *et al* 1997; Bienefeld *et al* 1999). It does, however, correspond with what was observed in hundreds of Cape honeybee colonies after the

arrival of the varroa mite. In the first weeks after varroa infestation it would be common to see a bee shaking itself, and attempting to remove a mite with its forelegs. Thereafter, and to the present day, no further efforts to groom varroa mites from their bodies have been witnessed. No attempts to groom mites from other bees have been seen during the study, despite the mites often being fully exposed and vulnerable on the thorax of worker bees.

The possibility that varroa mites were insufficiently attracted to the brood of Cape honeybees, and that this contributed to varroa tolerance, can also be discounted. Cape worker brood is found to be just as attractive as is brood of the Savanna honeybee (Table 5.7 & Table 5.8). Furthermore, the huge numbers of varroa mites found in Cape honeybee colonies between 1997 and 1999 (Appendix I) clearly demonstrated that varroa mites were attracted to *A.m. capensis* brood.

The possibility that South African pseudoscorpions were preying on varroa mites in honeybee colonies, and hence served as a biocontrol agent on the mite population growth, can also be discounted. Practically no pseudoscorpions were found during an extensive survey (Table 5.11), including surveying those colonies of beekeepers that suggested that they might control varroa mites. Pseudoscorpions are so rare in South African honeybee colonies that they cannot possibly be having any effect on varroa mites. It is considered highly unlikely that the numbers presented in Table 5.11 significantly underestimate the numbers of pseudoscorpion present, as they are extremely visible and frequently run out of the hive as soon as it is disturbed. Also, the low numbers are unlikely to be due to a seasonal absence, as colonies were sampled over a nine-month period. Finally, no pseudoscorpions were found in the Western Cape, confirming previous sampling records (Dippenaar-Schoeman & Harvey 2000), even though varroa tolerance is most pronounced in this province. No evidence could be found that pseudoscorpions could act as significant predators of varroa mite and captive pseudoscorpions also failed to consume either live or dead varroa. There is no basis to believe that South African pseudoscorpions could be valuable in varroa biocontrol.

The remaining three factors examined as possibly contributing to the varroa tolerance found in Cape honeybees, namely the short post-capping time of Cape bees, the greater levels of hygienic behaviour of African bees and the high degree of mite infertility, were all considered to be contributing elements to varroa tolerance found in South Africa.

At first glance hygienic behaviour does not seem to be a significant factor in the development of varroa tolerance by Cape honeybee. Hygienic behaviour, the removal of the mites from varroa-infested brood cells, has been most widely investigated of all the factors considered to be important for varroa tolerance (Boecking & Drescher 1991; Boecking & Drescher 1992; Spivak 1996; Spivak & Reuter 1998). Cape honeybee colonies all appear to be more hygienic than are European colonies (Spivak & Gilliam 1998) with an average of 58% of dead brood being removed within 24 hours, and almost 100% of dead brood being removed within 48 hours (Figure 5.3). There was, however, no correlation between this hygienic trait and varroa infestation rates (Table 5.4) and hygiene seemed ineffectual

against varroa mite problems as ten of the twenty colonies monitored died within 18 months. Hygienic behaviour was, however, significantly correlated with hive mortality, with those colonies with poor hygiene succumbing more rapidly that those with better hygiene (Table 5.4). These results suggest that hygiene confers some resistance to varroa mites, in terms of longer survival, but no long term tolerance to the mite. It is striking that hygiene levels in colonies vary so dramatically, suggesting that removal rates are very influenced by environmental effects, and that the repeatability of tests is low (Büchler 1994).

The problem in most hygiene experiments designed to directly monitor varroa removal is that they use artificially-infested cells which can elicit unnatural responses. The cell can be damaged and attracts undue attention from the honeybee workers, the condition of the introduced mite is often inappropriate, the age of the larva or pupa in the cell is always inappropriate, and there might be an alien scent on the introduced mites (Rosenkranz *et al* 1993). For this reason the "natural" half-comb method (Boot *et al* 1992; Beetsma *et al* 1993) was used. Only 9% of infested cells were found to be detected and the contents removed (Table 5.5), this being considerably less than that reported in previous studies (Boecking & Drescher 1991; Boecking & Ritter 1993; Spivak 1996). Once again there is no obvious indication that hygienic behaviour is important in the varroa tolerance of Cape honeybees. It should be noted, however, that removal rates varied from 2% to 40% between colonies (Table 5.5), once again offering great potential for selection (Spivak & Reuter 1998).

Results from the inspection of the post-capping development time of Cape honeybees are more promising. The reproduction of varroa only occurs inside sealed brood cells (Ifantidis & Rosenkranz 1988). After the invasion of a brood cell the mother mite lays up to 6 eggs in 30-hour intervals, the first being a haploid male that must mate with his sisters before they emerge from the sealed cell (Ifantidis 1983; Martin 1994). Obviously the duration of sealed brood strictly limits the number of offspring that may reach the adult stage and honeybee strains with a short post-capping time are likely to be more tolerant to varroa mites, and the mites in these strains more dependent on reproduction in drone cells. The post-capping period of Cape honeybees appears to be shortest of all *mellifera* races, with a peak between 259-269 hours but in some cases as short as 241 hours or as long as 281 hours (Table 5.10). This is markedly shorter than the 281 hours of *A.m scutellata* (Martin & Kryger 2002) and 282 hours in European bees (Martin 1994). These data correspond well with published reports of *A.m. capensis* post-capping time (Moritz and Hänel 1984; Moritz & Jordan 1992; Beekman *et al* 2000; Calis 2001; Martin & Kryger 2002). As the male mite moults only 222 hours after cell capping, and is only ready to mate 240 hours after cell capping (Donzé *et al* 1998), these post-capping limitations in Cape bees will certainly result in unmated mites and an increase in mite infertility. Ultimately, this increase in mite infertility will increase the dependence on drone brood for successful reproduction and accelerate the development of varroa mite tolerance in the population. Moritz & Hänel (1984) report that a 9.7 day (233 hours) development time in Cape honeybees results in only 21% of the mites in worker cells being able to successfully reproduce.

The post-capping data is strikingly variable, and highly suggestive. As it varies from 241 hours to 281 hours, and also varies quite significantly between colonies, it might well be the case that extreme selection is imposed by the mite on the Cape honeybee population for a shorter developmental time. Other reports have also indicated this extreme variability in post-capping period. Schousboe (1986; cited in Büchler 1994) found a 28 hour variation in post-capping period in a colony of European bees, and Büchler and Drescher (1990) found up to 19 hours variation. There is also apparently a very noticeable seasonal effect (Schousboe 1990; cited in Büchler 1994) which might explain to some extent the variability of results (Table 5.10).

The contribution of short post-capping period can readily be seen in the analysis of the reproductive fate of varroa mites in Cape honeybees. 34% of female mites in worker cells fail to produce a viable female before the worker bee emerges, as against only 2% of female mites in drone cells (Table 5.9). This can only be due to the shorter post-capping period for worker brood, and the effect can be seen in the 25% of foundresses that failed to reproduce at all in both worker and drone brood cells (Table 5.9). These were unmated females from previous generations, daughter mites that emerged from a worker brood cell before daughters could be adequately mated by their brother. As a result, there was 61% non-reproduction in Cape honeybee worker cells and 28% non-reproduction in drone cells. These data correspond well with the mite infertility rates that have been found in other varroa-tolerant honeybee populations (Ritter & De Jong 1984; Camazine 1986; Engels *et al* 1986; Rosenkranz *et al* 1990; Rosenkranz & Engels 1994; Martin *et al* 1997; Medina & Martin 1999). Only 2% of the infertility (that in the drone cells) could be ascribed to other suggested causes of infertility such as seasonal effects (Otten & Fuchs 1990; Kulinčević *et al* 1988), the age of bees (Büchler 1994), or some signal delaying or preventing mite oviposition (Garrido *et al* 2000; Garrido & Rosenkranz 2003), or male mortality in brood cells (Martin & Medina 1999). The rest of the infertility (32%) was due to the short post-capping period that prevented sufficient mating of daughter mites from being completed (Harris & Harbo 1999). The reproductive fate of varroa in these Cape honeybee colonies was quite discordant from previous results in that practically no dead females were found in cells. Previous reports have indicated from 2-16% of the mothers were dead (Kusterman 1990; Fries *et al* 1994; Martin 1994; Martin 1995a; Donzé *et al* 1996; Martin *et al* 1997; Medina & Martin 1999; Martin & Kryger 2002). The large number of dead mites (females and males) found by Martin & Kryger (2002) were not found in this study. They were, in all probability, not caused by the additional feeding to Cape pseudo-clones which reduced the space in the cells and caused mite mortality, as suggested, but rather by the very poor quality of most Cape pseudo-clone brood, caused by insufficient feeding and poor temperature regulation in advanced pseudo-clone colonies, which results in very poor brood emergence (Allsopp unpublished data).

It should be stressed that the results obtained are from naturally infested brood frames, and not from artificially-infested cells, as these techniques have severe limitations. These concerns primarily involve experiments where mites have been harvested from colonies by some means, and then artificially introduced into sealed brood cells, and the reproductive fates of these mites recorded. This introduces

at least four areas of error and variability: (a) effect on the mites of the harvesting procedure; (b) introduction of mites not in the appropriate stage of their life cycle; (c) introduction into brood cells that are “too old” as well as being of variable age; and (d) damage to the cell cappings that can cause the cells to be opened and the brood to be removed.

Although the short post-capping period of Cape honeybees clearly contributes to the level of infertile mites in the Cape population, is this sufficient to explain the tolerance of Cape honeybees to varroa mites? The answer is clearly no as evidenced by the huge numbers of mites found in Cape colonies from 1997 to 2000 (Appendix I). The lengthy availability of drone brood and the 40% success rate in worker brood is clearly sufficient to sustain rapid varroa population growth, the 60% non-reproduction in worker cells notwithstanding.

The answer to the puzzle as to what confers varroa tolerance on Cape honeybees can be found in recent discoveries by Ibrahim & Spivak (2004) and Harbo & Harris (2005). Ibrahim & Spivak (2004) reported that the Suppressed Mite Reproduction (SMR) population of Harbo & Harris (2001) was very hygienic. This was investigated further by Harbo & Harris (2005) and the link between hygienic behaviour and mite infertility was found. “Suppressed Mite Reproduction” was found to be an artefact, and entirely dependant on the behaviour of the worker bees in the colonies, and not on some feature of the mites within the brood cell. Harbo and Harris (2005) used colonies from their highly SMR line, in which only 3% of mites were reproductive, and from their non-SMR line where 80% of mites were fertile in worker cells. They deposited recently sealed brood frames from a single donor source having large numbers of mites into colonies of these two lines and found that only 2.2% of worker cells in the SMR colonies were varroa infested while 9.0% of the worker cells in the non-SMR colonies were varroa infested. Furthermore, only 20% of mites were reproductive in the SMR colonies compared to 71% in the non-SMR colonies. The implications of these results are quite obvious, and extremely significant. The hygienic response of SMR colonies is much greater than that of non-SMR colonies, and in these colonies there is the selective removal of reproductive mites. SMR bees remove reproductive mites, responding to some feature of the reproductive process, leaving the non-reproductive mites. If these brood frames are examined only at the emergence of the worker brood, there is a high percentage of non-reproductive mites in the brood, which has always been considered as “mite infertility”. This becomes more pronounced with successive generations of individuals that express this characteristic, as the degree of “mite infertility” increases.

Therefore, what the results of Harbo & Harris (2005) indicate is that “suppressed mite reproduction” is nothing of the sort. Rather, hygienic behaviour (the removal of varroa mites from infected brood cells) is shown to be the removal of reproductive varroa mites from infected brood cells, and not the removal of all mites in brood cells. This single insight relates varroa hygiene to “mite infertility” and to varroa tolerance, and largely explains the derivation of varroa tolerance in honeybee populations of Brazil, Tunisia and South Africa. The ability to selectively remove reproductive mites from worker brood cells, and the constant selection against reproductive mites in these colonies, will inevitably result in an

increase of non-reproductive mites in the colony and a varroa population level insufficient to result in colony damage. This scenario is well supported by empirical data, with the level of infertile mites increasing with time as the "reproducing" mites are detected and removed. Calderón *et al* (2003) found that 70% of mites in worker cells of Africanized bees in Costa Rica reproduced, and the infertility of varroa mites in worker cells of Africanized honeybees in Mexico is only between 4-18% (Medina & Martin 1999; Vandame *et al* 1999; Medina *et al* 2002), These data reflect the early stages of varroa infestation, and indicate that Africanized bees (and African bees) do not have an immediate tolerance to varroa mites. Rather, the level of infertile mites develops with time to reach the levels reported in Brazil, Uruguay and in selected stock in the USA (Ruttner *et al* 1984; Ritter & De Jong 1984; Harbo and Harris 2005), and with it varroa tolerance.

If the value of hygienic behaviour with regards to varroa is the removal of reproductive mites only, then it is not surprising that the monitoring of general hygienic response with respect to varroa infestation rates yielded negative results (Table 5.4). Similarly, the results on direct varroa removal (Table 5.5). Tests to relate hygiene response with varroa should now focus only on the removal of reproducing mites. It should also be considered that while only 9% of infected cells were removed in the direct assessment, this study was done in 2002, when colonies were already essentially varroa tolerant, and when the bulk of mites in the colony could be expected to be infertile. Mite removal figures in Cape colonies are likely to have been much higher during the early stages of varroa infestation.

Of the many features suggested to be important in the varroa tolerance of African or Africanized bees [shorter development time (Camazine 1986; Medina & Martin 1999); better grooming (Corrêa-Marques & De Jong 1998); better hygienic behaviour (Moretto *et al*1993; Guzman-Novoa *et al*1996; Boecking & Spivak 1999)], both the short post-capping period and the hygienic capabilities of African bees are found to be important. As an immense mite population developed (Appendix I), the environment is considered not to have played a role in varroa tolerance in South Africa. Also disregarded are suggestions that mite infertility and varroa tolerance were due to the particular population of mite involved (Anderson 1994; Boot *et al* 1999) and not a characteristic of the tolerant honeybee population. This too is shown not to be the case by the initial massive varroa population in South Africa, followed by mite population decline (Chapters 2 & 3). The most virulent varroa mite known, the Korean haplotype of *Varroa destructor*, has not overwhelmed the Cape bees in South Africa.

Most reports on varroa-tolerant populations suggest that tolerance to varroa is a multifactorial phenomenon (Rosenkranz 1999), somehow involving mite infertility. This is suggested not to be the case, except in Cape honeybees. In all other populations and types of bees, hygiene behaviour (= the selective removal of reproducing mites) is suggested to be the sole basis of varroa tolerance. Some populations, chiefly African bees, are more hygienic than others, and likely to become varroa tolerant more rapidly. As reproductive mites are removed from cells, the percentage of infertile mites (from whatever source) increases, and the population soon reaches equilibrium as regards the varroa infestation. This is the situation in the natural host of varroa. Anderson (1994) and Boot *et al* (1999)

moved mites from *Apis cerana* onto *Apis mellifera* and found that very few of them were able to reproduce. They concluded that some effect of the host results in a permanent change in the mite but it should now be clear that this "effect" is the constant removal of reproducing mites by *Apis cerana,* leaving only a non-reproducing mite population.

It is suggested that a "normal" infertility of about 2-10% is found in most mite populations, probably brought about by site initiation problems, insufficiently mated females, and females that have used all their spermatozoa. This is probably the level found in normal unselected European honeybee populations. Selection for the removal of reproductive mites can increase the level of infertile mites to almost 100% (Harbo & Harris 2005). In African bees, hygienic behaviour is more intense (Moretto *et al* 1991; Loper 1995; Corrêa-Marques & De Jong 1998; Guerra *et al* 2000) and varroa tolerance occurs more rapidly and with fewer losses than with European bees. This is probably what happened in Brazil and Tunisia. Varroa tolerance in Brazil developed apparently without the loss of colonies (De Jong *et al* 1984; Moretto *et al* 1991) but it is more likely that there was a substantial loss of colonies, perhaps 30-50%, similar to the experience in South Africa, but with no widespread population decline and with population-wide tolerance developing within approximately five years. This was the situation in Tunisia where varroa was first detected in 1975. There were heavy colony losses in 1978-79 and then varroa numbers stabilized and the colony losses stopped (Ritter 1990). The same scenario is suggested to have played out wherever varroa tolerance has developed, with the natural level of hygienic response and the extent to which the honeybee population has been left to natural selection the factors that determine the speed of population-wide tolerance.

Only in Cape honeybees is an additional factor thought to be at play, that of the short post-capping period. In European bees, the presence of non-mated mites as a result of short post-capping periods has been suggested as contributing to conferring varroa tolerance (Harris & Harbo 1999). Garrido & Rosenkranz (2003), however, found that 100% of phoretic mites in a colony of bees with a mite population that was 16% infertile had spermatozoa in their spermatheca, suggesting that the non-mating explanation was not correct. Calis *et al* (1996) also found no differences in juvenile mortality in worker cells between *A.m. capensis* and *A.m.carnica*. This clearly demonstrates that the differences that were found between Cape honeybees and European bees are due to the shorter post-capping period, and not due to male death or foundress death taking place inside the brood cell. The short post-capping period of Cape honeybees dramatically increases the percentage of unmated and non-reproductive mites in the colony, and reduces the time period necessary for hygienic responses to weed out reproducing mites. The selective removal of reproductive mites, the shorter post-capping period for Cape worker brood and the high level of hygienic behaviour of African bees resulted in the extremely rapid development of varroa tolerance in Cape bees.

CHAPTER SIX
GENERAL DISCUSSION

The discovery of the varroa mite (*Varroa destructor*) in South Africa in 1997 raised the possibility of mass losses and even destruction of the honeybee populations in South Africa, both managed and wild, as has occurred in most parts of the world where the varroa mite has become established. This was reinforced by the fact that the mite in South Africa was positively identified as the Korean-haplotype of *Varroa destructor*, the variant responsible for the world-wide damage. While it has now been established that the varroa mite has spread throughout South Africa (Chapter 2; Figures 2.1–2.5), as was expected, the predicted decline of the honeybee populations has not materialized. The spread of varroa was facilitated by commercial beekeeping activity, with mites being rapidly transported from the Western Cape to Kwazulu-Natal, and later also into the Eastern Cape. Varroa has also spread into the wild honeybee populations and has been found in all natural populations monitored except one (Figure 2.6). Furthermore, the expectation that varroa would be an African problem and not a South African problem (in contrast to the Capensis Problem) has also being realized, with the presence of varroa mites already confirmed in four neighbouring countries (Botswana, Swaziland, Zimbabwe, Mozambique). The expectation that varroa mites will spread throughout sub-Saharan Africa within the next decade is highly likely.

As South Africa has the same type of varroa mite that has caused widespread decline of honeybee populations throughout the world, the Korean mitotype of *Varroa destructor* (Anderson 2000), a similar impact had been predicted for South Africa (Martin & Kryger 2002). Since South Africa is neotropical, it was thought that our honeybees would be particularly vulnerable to the mite, and colony deaths were predicted to occur in less than a year (Kraus & Page 1995b; Calis 2001), quickly followed by population decline. This expectation has not been realized, however, and while the mite showed rapid population growth and spread, colony and population declines in South Africa were certainly not on the scale witnessed in other parts of the world. In periods of initial exposure to the mite, the “front” of the spread of varroa, mite populations built up extremely rapidly in the honeybee colonies of South Africa, even dramatically. As many as 50 000 mites were found in commercial colonies, and average mite numbers of more than 10 000 per colony (Table 2.2; Table 3.2; Appendix 1) were found. This initial surge in mite population growth was accompanied by all the classic symptoms of varroa mite damage (scattered brood pattern; bees with vestigial wings; large amounts of chalkbrood; “disappearing” colonies), and it appeared that the pattern being followed was similar to that witnessed elsewhere (Bailey & Ball 1991). During this initial stage, colony decline and mortality was not unusual, and entire apiaries were lost to what was demonstrably varroa damage (Table 3.2; Appendix II), to the extent that many commercial beekeepers quickly turned to varroacide treatments to protect their colonies. Colony losses were sporadic, however, and the population-wide colony losses reported in

other parts of the world (e.g. Finley et al 1996; Page 1998) did not eventuate in the population of Cape honeybees. The large-scale monitoring of *Apis mellifera capensis* commercial colonies for varroa mites (Figure 3.6) revealed that even if honeybee colonies were not necessarily dying because of varroa, colony vitality decreased as mite numbers increased (Table 3.6). Colonies infested with varroa mites were also found to less effective as pollination units (Table 3.7), although only at high levels of varroa infestation. There was no indication of tracheal mites being involved in this negative impact on Cape colonies, as tracheal mites were found to have decreased in abundance to a level where detection was difficult. Additionally, in an assessment of the relative importance of varroaosis and the Capensis Problem in the mortality of colonies, there was no correlation between varroa mite infestation and Cape honeybee infestation of these colonies (Table 3.11). Once again varroa infestation was not significantly correlated with colony mortality.

The only conclusion that could be reached during the monitoring of varroa mites in South Africa was that, while they were having a negative effect on both Cape and Savanna honeybee populations, colony losses of the order witnessed in other parts of the world were not taking place in South Africa. Although brood infestation rates are equivalent to those reported for other bee races and strains (Table 4.1), mite population growth in both Cape and Savanna honeybee colonies was not what was expected. This was especially the case in the Cape honeybee where the mite population in the colonies increased slowly for approximately 100 days, and then tailed off (Figure 4.3). After a period of more than a year, the mite numbers in these Cape honeybee colonies remained very low. Definitive support for the mite tolerance in Cape honeybees may be found in the monitoring of honeybee colonies in a nature reserve (Table 5.1), with honeybee colonies free of commercial beekeeping stresses and also possible varroacides, and in the repeated assessment of commercial Cape colonies over time (Table 5.2). In both cases the mite population was found to have rapidly decreased after an initial surge, demonstrating the rapid development of varroa mite tolerance in these honeybees. The results were particularly significant in the Cape of Good Hope wild population, which had been monitored on a regular basis from before the arrival of the varroa mite in South Africa to date. These data, from a wild *Apis mellifera capensis* population, illustrate the rapid development of mite tolerance, with mite numbers reduced to practically zero after not much more than three years of exposure. These data, which are presently being confirmed by similar results from two other Cape nature reserves, indicated that Cape honeybees will rapidly develop complete tolerance to varroa mites in as little as three years, if left untreated, and with manageable colony losses. A “live-and-let-die” treatment regime is the recommended response to varroa mites for Cape bees, and is well supported by the data. While the Africanized bees of Brazil are reported to have rapidly developed tolerance to the varroa mite (eg Rosenkranz & Engels 1994, De Jong 1997), the Cape Point population is the first in which the development of tolerance has been recorded from first exposure until full tolerance.

In the population dynamics assessment of the *Apis mellifera scutellata* colonies, the mite population also increased very slowly for approximately 300 days, and then exhibited an exponential increase (Figure 4.4). After one year, the mite population in the Savanna honeybee colonies was 700 times that

of the Cape colonies. Nonetheless, even in these colonies, the mite population was found to have increased far more slowly than has been predicted for neotropical honeybees (Calis 2001) and wide-scale colony mortality resulting from varroa mites was not evident. The explanation initially favoured was that these honeybees, having not been exposed to the varroa mite for as long as the Cape bees, were still in the process of developing tolerance to the mite, and hence mite population growth was more substantial than in the Cape colonies. Continued monitoring of honeybee colonies from Kwazulu-Natal, until early 2005, indicated that mite populations in honeybee colonies from this region remain relatively high, and are much higher than are present in Cape honeybee colonies at the same time. This suggests an incomplete tolerance in these colonies, or perhaps a different tolerance mechanism. No clear mite-tolerance could be detected in the Savanna bee population, but there clearly was no population-wide decline. In the most recent assessment of colonies from the Kwazulu-Natal midlands, however, the situation was found to have changed dramatically. In October 2005 recently-trapped *A.m. scutellata* in the vicinity of Ixopo and Richmond were examined for varroa mites. This region has recorded the highest mite infestation rates in South Africa (Appendix I) and varroa has been present since 1998 (Figure 2.3). In the most recent results varroa numbers were negligible (n = 12 colonies; mites per 100 bees collected from the brood nests = 0.58 ± 0.17 per colony), a dramatic decline from the year before. It appears that varroa tolerance has developed in this Savanna honeybee population, and the development took 6-7 years in comparison with the 4-5 years of the Cape honeybee population.

This conclusion is supported by data from the monitoring of wild, unmanaged African honeybee colonies in nature reserves. These colonies have not been monitored for as long as have the Cape colonies, and fully definitive data has yet to be obtained. It is evident, however, that as with the Cape colonies, mite numbers in the wild Savanna colonies are much lower than in the commercial Savanna colonies. Furthermore, mite numbers in these wild colonies have already begun to drop, as was the case in the Cape colonies, suggesting that mite tolerance in these colonies is developing, once again without large scale colony losses. Perhaps varroa numbers have remained high in the commercial Savanna honeybee colonies because of some reduced capacity in these colonies brought about by the Capensis Problem, a reduced capacity preventing the development of mite tolerance in these colonies. Note that the Savanna colonies monitored in the wild areas do not have the Capensis Problem. It could be that many of the colonies in the Savanna honeybee region of South Africa simply don't remain alive long enough, due to Cape Honeybee problems, to readily develop complete tolerance to the varroa mite. Based on the most recent data from Kwazulu-Natal, near-complete tolerance to varroa mites can be expected throughout the *Apis mellifera scutellata* parts of South Africa in the near future. It is already safe to conclude that near complete tolerance exists in the Cape honeybee. The population monitoring data (Figure 4.3), hygiene monitoring (Table 5.3), Capensis Problem monitoring (Figure 3.3), the monitoring of Cape Point colonies (Table 5.1), as well as the monitoring in other nature reserves and the commercial bee populations (Table 5.2), all show a varroa population increase and then decrease. Add to this that no population wide decline has been reported (Figure 3.3; Appendix I), it is safe to conclude that Cape honeybees are varroa-tolerant.

As regards the factors responsible for the tolerance of Cape honeybees to varroa mites, and the lesser tolerance of Savanna bees, there is no definitive answer. It is abundantly clear, because of the huge numbers of mites in colonies, that the honeybee populations (both Cape and Savanna) were not immediately resistant to varroa (Appendix I). It is also clear that the tolerance did not result from the elimination of 99% of the population, and re-colonization by the few survivors. Rather, for the most part, varroa tolerance in South Africa developed within surviving colonies with only the most susceptible colonies dying.

Most of the multitude of reasons suggested as possible causes of mite tolerance were examined. It should be noted that no single resistance mechanism is considered to be responsible for the varroa tolerance of honeybee populations in Russia, Arizona and Kentucky (Erickson et al 1998; De Guzman et al 2002). Rather, an amalgam of many different traits both behavioural and physiological is considered to be responsible for the tolerance. In the mite tolerance in African bees, this smorgasbord of tolerance-inducing characteristics appears not to be the case. The direct aggression of African honeybees to varroa mites, the presence of a natural biocontrol agent, and the attractivity of brood to mites could all be excluded as possible causes of tolerance, leaving only hygienic behaviour and the short post-capping period of Cape honeybees as the cause of mite tolerance. These are, however, considered sufficient to explain the in-hive development of mite tolerance in African bees.

The only essential characteristic necessary to explain the tolerance is the ability of honeybee workers to detect and remove reproducing mites (Harbo & Harris 2005), and to leave non-reproducing mites. This hygienic response is well developed in African and Africanized bees (Moretto *et al* 1991; Loper 1995; Corrêa-Marques & De Jong 1998; Guerra *et al* 2000; Fries & Raina 2003), and is highly heritable (Boecking & Drescher 1991; Boecking & Drescher 1992). The seemingly continent-wide tolerance of African bees to American Foulbrood (Fries & Raina 2003) suggests that hygienic behaviour may be very well developed in African bees and will lead to the percentage of reproducing mites in a colony being systematically reduced, without the colony succumbing to the mites. This characteristic and this characteristic alone is all that is necessary to explain the varroa tolerant mite populations found around the world.

In the case of Cape honeybees, it is obvious that the short post-capping period plays an additional role. The post-capping period of Cape honeybees appears to be shortest of all *mellifera* races, mostly from 259-269 hours but in some cases as short as 241 hours (Table 5.11). This is markedly shorter than the 281 hours of *A.m scutellata* (Martin & Kryger 2002) and 282 hours in European bees (Martin 1994). While this short post-capping period does not prevent reproduction in Cape honeybees (Martin & Kryger 2002) it certainly limits reproduction, increases the percentage of infertile mites in the population and accelerates the development of varroa mite tolerance in the population. Together the short post-capping period and the selective removal of reproductive mites have reduced mite fertility in worker cells in Cape bees to 39%, a figure that has probably been further reduced since 2002. Harbo

& Harris (2005) have shown that selective breeding can reduce mite fertility to as little as 3%. Cape honeybee workers are considered to have induced a gradual tolerance to varroa mites by their active removal of reproducing mites and by their extra-short post-capping period. This tolerance has spread and manifested itself throughout the population by beekeepers letting susceptible colonies die.

In-hive tolerance in Cape bees, that is, the survival and recovery of colonies infested and damaged by varroa mites, is therefore concluded to be the result of the effective removal of reproductive mites and the short post-capping period of Cape honeybees. Selective breeding must be added to this in-hive recovery to fully explain the rapid development of varroa tolerance in the Cape honeybee. It should be remembered that varroa infestation will exert direct pressure on the drones of infected colonies (Allsopp 1999; Jandricic & Otis 2003).There is strong selection on drones because drone brood is greatly preferred to worker brood (Boot et al 1992). Parasitized drones show significant weight loss (Rinderer et al 1999), reduced sperm levels (Collins & Pettis 2001), a decreased lifespan (Rinderer et al 1999) and reduced flight activity (Pechhacker 1998). Colonies heavily infested with varroa therefore contribute little to the available drone population, and hence to the next generation. It might be expected that the some conclusion would apply to the production of viable swarms (Engels et al 1986). Together these suggest that survivor colonies, those that are most tolerant of varroa and are able to keep varroa levels low, rapidly dominate the reproductive population (Allsopp 1999; Jandricic & Otis 2003). The selection of a tolerant honeybee population is likely to occur rapidly under these conditions. In general, selection in haplo-diploid populations is 30% more rapid than in diplo-diploid populations (Jandricic & Otis 2003).

In summary, Cape honeybees (*Apis mellifera capensis*) were found to be largely tolerant of the varroa mite (*Varroa destructor*). This tolerance extends to practically all Cape honeybee populations, although those in more remote regions are not fully tolerant as yet. The varroa tolerance in Cape bees is likely to be a permanent phenomenon provided the population remains unmanaged and under constant selection pressure. There are reports from Brazil about Africanized bees becoming susceptible after 20 years of tolerance (Guzman-Novoa *et al* 1999) but this is likely to be because of the arrival in Brazil of the more virulent Korean haplotype. As South Africa already has the Korean haplotype, and Cape honeybees are tolerant to the mite, this tolerance is expected to be permanent. The tolerance in Cape bees is a result of effective hygienic behaviour and the short post-capping period, and together they have resulted in varroa tolerance in a short period of time. To further elucidate the development of varroa tolerance it would be very instructive to examine the Robben Island Cape honeybee population, which has never been exposed to the varroa mite, to compare varroa removal from brood cells and post-capping time, with the mainland population. As for the Savanna honeybee, the developing tolerance would appear to result only from effective removal of varroa-infested brood from brood cells, as the post-capping period appears to be much the same as that of European bees (Martin 1994; Vandame 1996; Martin & Kryger 2002). It would be a worthy exercise to carefully determine the population post-capping period of *Apis mellifera scutellata*, to determine if this plays a role in varroa tolerance. However, the enhanced hygienic behaviour in

Savanna bees should be sufficient for varroa tolerance to develop, and to develop in less time than is the case in less hygienic European honeybee strains. The fact that varroa mite tolerance exists in Africanized populations and is well advanced in *A.m. scutellata* populations (this study), is proof that a short post-capping period is not a prerequisite for mite tolerance. Rather, it only serves to rapidly accelerate the tolerance. The dual prerequisites for varroa tolerance appear to be honeybee hygienic behaviour allowing the worker bees to selectively eliminate reproducing mites (Harbo & Harris 2005), slowly increasing the percentage of infertile mites in the population, and for the honeybee population to be unmanaged and free of chemical protection, to allow selection to take place and for varroa tolerance to develop. The speed with which mite tolerance will develop will depend on population post-capping time and population hygienic behaviour, but there appears no reason why it would not develop in any honeybee population, given enough time.

Notwithstanding the characteristics of African honeybee races that pre-adapt them to varroa tolerance, the lack of breeding and artificial selection in African honeybees is certain to be a critical factor in varroa mites not becoming a major problem in South Africa as it has almost throughout the world. Varroa tolerance requires constant selection pressure to maintain the tolerance, the selection pressure provided by free-mating and unmanaged colony survival. In contrast, a very large proportion of the commercial beekeeping industry in the USA depends on the purchase of commercially-produced queens with limited genetic variability, which are often poorly mated and infected with various pests and diseases (Camazine et al 1998). A similar situation exists in commercial beekeeping operations around the world. To compound it, beekeepers are forever introducing bees from across the globe in an effort to deal with local pests and diseases. All in all, the commercial bee population is generally not genetically diverse and not locally adapted. This is in complete contrast to the African honeybee population which is almost totally unselected, and probably as genetically diverse now as it was a thousand years ago. Bailey (1999) and Allsopp (1999) have argued that selective breeding for “quality” by and for beekeepers has decreased the resistance in honeybee populations to a wide range of pathogens. Highly intensive selection has decreased genetic variability and selected against critical “bee tolerance” factors such as swarming and defensiveness (Bailey 1999). A more sensible approach would be to: (a) Manage naturally occurring regional strains of honeybee, rather than importing strains from elsewhere. This is particularly important in Europe and Africa where *Apis mellifera* is indigenous and less so where it is an exotic species. (b) Practise “primitive” beekeeping as is the case in Africa by allowing natural selection processes to determine which are the most significant characteristics for selection and not the beekeepers or bee scientists, at least to some extent. It is also best to use an un-manipulated wild population, and for this population to be as large as possible.

Other researchers (e.g. Danka et al 1997; Rinderer et al 2001) have argued that there would be no natural resistance to varroa, and that all unmanaged colonies would be eliminated with only especially bred commercial stock being able to survive. Chemical or biotechnical treatment of colonies (Van Dung et al 1997; Goodwin & Van Eaton 2001), and the breeding of selected stock to develop resistance (Rinderer et al 2001), are held as the only way to maintain colonies faced with the varroa

mite. There have also been suggestions that this resistance needs to be maintained through controlled mating and/or gene based selection made possible by the Honeybee Genome project (Evans 2005), much as happens in many varieties of livestock and plant crops. The existence of naturally occurring varroa tolerant honeybee populations around the world makes a mockery of these claims, and I would argue that this methodology, albeit seductive, would be ineffective, as has been the case with bee breeding in general. Captive breeding programmes and especially gene selection programmes can never adequately keep up with the changing environment, certainly not to the extent that a “live-and-let-die” approach can. Allowing natural selection to determine who the winners are, will always be the most sensible strategy. This may not sit well with generations of bee-masters and bee scientists, but the dominance of unmanaged bees takes some explaining away. The success of *A.m.scutellata* in the Americas and the failure of bee diseases in Africa, are two examples that support this approach.

Finally, and given the demonstrated varroa tolerance in African honeybee populations, action should be taken in Africa to make sure than pesticides are not inappropriately used (dumped), and that beekeepers are trained so that they may ride-out the colony losses, to allow for the development of varroa tolerance that is widespread and permanent.

REFERENCES

Allen MD (1965). The effect of a plentiful supply of drone comb on colonies of honeybees. **Journal of Apicultural Research** 4, 109-119.

Allen MF & Ball BV (1996). Incidence and world distribution of honeybee viruses. **Bee World** 77, 141-162.

Allsopp MH (1992a). The *capensis* calamity. **South African Bee Journal** 64, 52-55.

Allsopp MH (1992b). Drifting and honey production. **South African Bee Journal** 64, 54-57.

Allsopp MH (1993). Summarized overview of the *capensis* problem. **South African Bee Journal** 65, 127-136.

Allsopp MH (1997a). The *capensis* problem and varroa - a marriage made in hell? **South African Bee Journal** 69, 82-85.

Allsopp MH (1997b). Tracheal mites in South Africa - time for a better look? **South African Bee Journal** 69, 93-95.

Allsopp MH (1998). Survey for *Varroa jacobsoni* in South Africa. **South African Bee Journal** 70, 145-154.

Allsopp MH (1999a). Might varroa cure the *capensis* problem? **South African Bee Journal** 71, 80-81.

Allsopp MH (1999b). Are selective breeding and stock maintenance possible in South Africa? **36th Apimondia Congress**, Vancouver, 11-18th September.

Allsopp MH (2001). Varroacides: use & abuse. **South African Bee Journal** 73, 172-173.

Allsopp MH (2004). Cape Honeybee (*Apis mellifera capensis* Eshscholtz) and varroa mite (*Varroa destructor* Anderson & Trueman) threats to honeybees and beekeeping in Africa. **International Journal of Tropical Insect Science** 24, 87-94.

Allsopp MH & Hepburn HR (1997). Swarming, supersedure and the mating system of a natural population of honeybees (*Apis mellifera capensis*). **Journal of Apicultural Research** 36, 41-48.

Allsopp MH, Govan V & Davison S (1997). Bee health report: varroa in South Africa. **Bee World** 78, 171-174.

Allsopp MH, Calis JNM & Boot WJ (2003). Differential feeding of worker larvae affects caste characters in the Cape Honeybee, *Apis mellifera capensis.* **Behavioural Ecology & Sociobiology** 6, 555-561.

Amdam GV, Hartfelder K, Norberg K, Hagen A & Omholt SW (2004). Altered physiology in worker honey bees (Hymenoptera: Apidae) infested with the mite *Varroa destructor* (Acari: Varroidae): a factor in colony loss during overwintering? **Journal of Economic Entomology** 97, 741-747.

Anderson AJ & Allsopp MH (1999). A preliminary evaluation of the organic control of *Varroa jacobsoni* in Cape Honeybees. **South African Bee Journal** 71, 12-20.

Anderson DL (1994). Non-reproduction of *Varroa jacobsoni* in *Apis mellifera* colonies in Papua New Guinea and Indonesia. **Apidologie** 25, 412-421.

Anderson DL (2000). Variation in the parasitic bee mite *Varroa jacobsoni* Oud. **Apidologie** 31, 281-292.

Anderson DL (2002). Varroa-bee relationships – what they tell us about controlling *varroa* mites on the European honeybee. **Apiacta** 37, 39-43.

Anderson DL & Fuchs S (1998). Two genetically distinct populations of *Varroa jacobsoni* with contrasting reproductive abilities on *Apis mellifera*. **Journal of Apicultural Research** 37, 69-78.

Anderson DL. & Trueman JWH (2002). *Varroa jacobsoni* (Acari: Varroidae) is more than one species. **Experimental and Applied Acarology** 24, 165-189.

Anderson RH (1963). The laying worker in the Cape Honeybee, *Apis mellifera capensis*. **Journal of Apicultural Research** 2, 85-92

Anderson RH (1965). The island breeding station. **South African Bee Journal** 37, 9-12.

ARC-PPRI (2001). **Synoptic Report on the Capensis Problem**. Plant Protection Research Institute, Pretoria, final report, 42 pp.

Arechavaleta-Velasco ME & Guzmán-Novoa (2001). Relative effect of four characteristics that restrain the population growth of the mite *Varroa destructor* in honey bee (*Apis mellifera*) colonies. **Apidologie** 32, 157-174.

Aumeier P (2001). Bioassay for grooming effectiveness towards *Varroa destructor* mites in Africanized and Carniolan honey bees. **Apidologie** 32, 81-90.

Aumeier P & Rosenkranz P (1997). Brood-attractivity and *varroa*-infestation: a comparison of Africanized and European bees. **Apidologie** 28, 182-184.

Aumeier P & Rosenkranz P (2001). Scent or movement of *Varroa destructor* mites does not elicit hygienic behaviour by Africanized and Carniolan honey bees. **Apidologie** 32, 253-263.

Aumeier P, Rosenkranz P & Gonçalves LS (1996). Defense mechanisms of honey bees against varroosis and brood diseases: comparison between *Apis mellifera carnica* and Africanized bees in Brazil. **Apidologie** 27, 286-288.

Bailey L (1999). The quest for a super-bee. **Bee World** 80, 55-60.

Bailey L & Ball BV (1991). **Honey bee pathology** (2nd ed.). Academic Press, London, 193 pp.

Bailey L, Ball BV & Perry JN (1983). Association of viruses with two protozoal pathogens of the honey bee. **Annals of Applied Biology** 103, 13-20.

Ball BV (1983). The association of *Varroa jacobsoni* with virus diseases of honey bees. *In* ***Varroa jacobsoni*** **Oud. affecting honey bees: present status and needs**, Cavalloro R (ed.). A.A. Balkema, Wageningen, pp. 21-23.

Ball BV (1985). Acute paralysis virus isolates from honey bee colonies infested with *Varroa jacobsoni*. **Journal of Apicultural Research** 24, 115-119.

Ball BV (1994). Host-Parasite-Pathogen interactions. *In* **New Perspectives on Varroa**, Matheson A (ed.). International Bee Research Association, Cardiff, pp. 5-11.

Ball BV (1997). Varroa and viruses. *In:* **Varroa! Fight the mite**, Munn P & Jones R (eds.). International Bee Research Association, Cardiff, pp. 11-15.

Ball BV & Allen MF (1988). The prevalence of pathogens in honey bee *Apis mellifera* colonies infested with the parasitic mite *Varroa jacobsoni*. **Annals of Applied Biology** 113, 237-244.

Beekman M, Calis JNM & Boot WJ (2000). Parasitic honeybees get royal treatment. **Nature** 404, 723.

Beetsma J & Zonneveld K (1992). Observations on the initiation and stimulation of oviposition of the *Varroa* mite. **Experimental and Applied Acarology** 16, 303-312.

Beetsma J, de Vries R, Emami Yeganeh B, Emami Tabrizi M & Bandpay V (1989). Effects of *Varroa jacobsoni* Oud. on colony development, worker bee weight and longevity and brood mortality. *In* **Present status of Varroatosis in Europe and progress in the Varroa mite control**, Cavallaro R (ed.). Commission of European Communities, Luxembourg, pp. 163-170.

Beetsma J, Boot WJ & Calis JNM (1993). Special techniques to make detailed observations of V*arroa* mites staying on bees and invading honeybee brood cells. In **Asian Apiculture**, Connor LJ (ed.). Wicwas Press, Chesire CT, USA, pp. 510-520.

Beetsma J, Boot WJ & Calis JNM (1999). Invasion behaviour of *Varroa jacobsoni* Oud.: from bees into brood cells. **Apidologie** 30, 125-140.

Benjiddou M, Leat N, Allsopp MH & Davison S (2001). Detection of Acute Bee-Paralysis Virus and Black Queen-Cell Virus in honey bees by reverse-transcriptase-PCR. **Applied & Environmental Microbiology** 67, 2384-2387.

Berg S, Büchler R, Kezic N, Pechhacker H, Ritter W, Sulimanovic D, Bienefeld K, Van Praagh J & Bubalo D (2001). Island project in Croatia: test of European honeybee strains for *Varroa* tolerance. **Apidologie** 32, 484-485.

Bermejo FJO & Fernádez PG (1997). Nosema disease in the honey bee (*Apis mellifera* L.) infested with varroa mites in southern Spain. **Apidologie** 28, 105-112.

Bienefeld K, Zautke F, Pronin D & Mazeed A (1999). Recording the proportion of damaged *Varroa jacobsoni* Oud. in the debris of honey bee colonies (*Apis mellifera*). **Apidologie** 30, 249-256.

Blum R (1989). Reproduction of *Varroa* in relation to protein supply of the honeybee colonies. **Apidologie** 20, 509-510.

Boecking O (1992). Removal behaviour of *Apis mellifera* colonies towards sealed brood cells infested with *Varroa jacobsoni*: techniques, extent and efficacy. **Apidologie** 23, 371-373.

Boecking O (1999). Sealing up and non-removal of diseased and *Varroa jacobsoni* infested drone brood cells is part of the hygienic behaviour in A*pis cerana*. **Journal of Apicultural Research** 38, 159-168.

Boecking O & Drescher W (1990). The reaction of worker bees in different *Apis mellifera* colonies to *Varroa* infested brood cells. *In* **Proceedings of the International Symposium on Recent Research on Bee Pathology**, Gent, Belgium, pp. 41-42.

Boecking O & Drescher W (1991). Response of *Apis meliifera* L. colonies to brood infested with *Varroa jacobsoni* Oud. **Apidologie** 22, 237-241.

Boecking O & Drescher W (1992). The removal response of *Apis mellifera* L. colonies to brood in wax and plastic cells after artificial and natural infestation with *Varroa jacobsoni* Oud. And to freeze-killed brood. **Experimental and Applied Acarology** 16, 321-329.

Boecking O & Drescher W (1998). **Research on *Varroa* resistant traits in European honey bee races.** EUROBEE AIR3-CT94-1064, EU, Brussels, final report, 22 pp.

Boecking O & Ritter W (1993). Grooming and removal behavious of *Apis mellifera intermissa* in Tunisia against *Varroa jacobsoni*. **Journal of Apicultural Research** 32, 127-134.

Boecking O. & Ritter W (1994). Current status of behavioual tolerance of the honey bee *Apis mellifera* to the mite *Varroa jacobsoni*. **American Bee Journal** 134, 689-694.

Boecking O & Spivak M (1999). Behavioural defenses of honey bees against *Varroa jacobsoni* Oud. **Apidologie** 30, 141-158.

Bogdanov S (1988). Bestimmung von Amitraz und seinen Metaboliten in Honig dursch HPLC. **Mitteilung der Sektion Bienen** 3, 1-9.

Bogdanov S, Imdorf A, Kilchenmann V & Gerig L (1990). Rückstände von Fluvalinat in Bienenwachs, Futter und Honig. **Bienenwelt** 32, 101-113.

Bogdanov S, Kilchenmann V & Imdorf A (1998). Acaracide residues in some bee products. **Journal of Apicultural Research 37**, 57-67.

Bolli HK, Bogdanov S, Imdorf A & Fluri P (1993). Zur Wirkungsweise von Ameisensäure bei *Varroa jacobsoni* Oud. und der Honigbiene (*Apis mellifera* L.). **Apidologie** 24, 51-57.

Boot WJ, Calis JNM & Beetsma J (1992). Differential periods of *varroa* mite invasion into worker and drone cells of honey bees. **Experimental & Applied Acarology** 16, 295-301.

Boot WJ, Sisselaar DJA, Calis JNM & Beetsma J (1994a). Factors affecting invasion of *Varroa jacobsoni* (Acari: Varroidae) into honeybee, *Apis mellifera* (Hymenoptera: Apidae), brood cells. **Bulletin of Entomological Research** 84, 3-10.

Boot WJ, Beetsma J & Calis JNM (1994b) Behaviour of *varroa* mites invading honey bee brood cells. **Experimental & Applied Acarology** 18, 371-379.

Boot WJ, Schoenmaker J, Calis JNM & Beetsma J (1995a) Iinvasion of V*arroa jacobsoni* into drone brood cells of the honey bee *Apis mellifera*. **Apidologie** 26,109-118.

Boot WJ, Driessen RG, Calis JNM & Beetsma J (1995b). Further observations on the correlation between attractiveness of the honey bee brood cells to *Varroa jacobsoni* and the distance from larva to cell rim. **Entomologia Experimentalis et Applicata** 76, 223-232.

Boot WJ, Tan NQ, Dien PC, Huan LV, Dung NV, Long LT & Beetsma J (1997). Reproductive success of *Varroa jacobsoni* in brood of its original host, *Apis cerana*, in comparison to that of its new host, *A. mellifera* (Hymenoptera: Apidae). **Bulletin of Entomological Research** 87,119-126.

Boot WJ, Calis JNM, Beetsma J, Hai DM, Lan NK, Toan TV, Trung LQ & Minh NH (1999). Natural selection of *Varroa jacobsoni* explains the different reproductive strategies in colonies of *Apis cerana* and *Apis mellifera*. **Experimental & Applied Acarology** 23, 133-144.

Bounias M, André JF, Nectoux M & Popeskovic DS (1994).*Varroa jacobsoni* control by feeding honey bees with organic cupric salts. **Bee Science** 3, 111-119.

Bowen-Walker PL, Martin SJ & Gunn A (1998). The transmission of Deformed Wing Virus between honey bees *Apis mellifera* L.) by the ectoparasite mite *Varroa jacobsoni* Oud. **Journal of Invertebrate Pathology** 73, 101-106.

Bowen-Walker PL, Martin SJ & Gunn A (1999). The transmission of deformed wing virus between honeybees (*Apis mellifera* L.) by the ectoparasitic mite, *Varroa jacobsoni* Oud. **Journal of Invertebrate Pathology** 73, 101-106.

Boylan-Pett W, Ramsdell DC, Hoopingarner RA & Hancock JF (1991). Honeybee foraging behaviour, in-hive survival of infectious pollen-borne Blueberry Leaf Mottle Virus and the transmission of the virus in highbush blueberry. **Phytopathology** 81, 1407-1412.

Branco MR, Kidd NAC & Pickard RS (1999). Development of *Varroa jacobsoni* in colonies of *Apis mellifera iberica* in a Mediterranean climate. **Apidologie** 30, 491-503.

Brødsgaard CJ, Ritter W, Hansen H & Brødsgaard HF (2000). Interactions among *Varroa jacobsoni* mites, Acute Paralysis Virus, and *Paenibacillus larvae larvae* and their influence on mortality of larval honeybees *in vitro*. **Apidologie** 31, 543-554.

Brødsgaard CJ, Hansen H & Wallner K (1998). Quality of honey on the Danish market: contents of *Paenibacillus larvae larvae* spores and pesticides. **Apidologie** 29, 261-262.

Büchler R (1989). Attractivity and reproductive suitability for the *Varroa*-mite of bee brood from different origin. *In* **Present status of Varroatosis in Europe and progress in the Varroa mite control**, Cavallaro R (ed.). Commission of European Communities, Luxembourg, pp. 139-145.

Büchler R (1990). Possibilities for selecting increased *Varroa* tolerance in central European honey bees of different origins. **Apidologie** 21, 365-367.

Büchler R (1992). Zucht auf Varroatoleranz. **Deutsches Imker-Journal** 3, 43-50.

Büchler R (1993a). Rate of damaged mites in natural mite fall with regard to seasonal effects and infestation development. **Apidologie** 24, 492-493.

Büchler R (1993b). Aufbau, Leistungsprüfung und Selektion der Kirchhainer Population. **Die Biene** 129, 11-17.

Büchler R (1994). Varroa tolerance in honey bees – occurrence, characters and breeding. **Bee World** 75,54-70.

Büchler R, Drescher W & Tornier I (1992). Grooming behaviour of *Apis cerana, Apis mellifera* and *Apis dorsata* and its effect on the parasitic mite *Varroa jacobsoni* and *Tropilaelaps clareae*. **Experimental & Applied Acarology** 16, 313-319.

Buys B (1995). First record in South Africa of the tracheal mite *Acarapis woodi*. **South African Bee Journal** 67, 75-78.

Cabras P, Floris I, Garau VL, Melis M & Prota R (1997). Fluvalinate content of Apistan® strips during treatment and efficacy in colonies containing sealed brood. **Apidologie** 28, 91-96.

Çakmak I, Aydin L, Gulegen E & Wells H (2003). Varroa (*Varroa destructor*) and tracheal mite (*Acarapis woodi*) incidence in the Republic of Turkey. **Journal of Apicultural Research** 42, 57-60.

Calatayud F & Verdu MJ (1995). Number of adult female mites *Varroa jacobsoni* Oud. on hive debris from honeybee colonies artificially infested to monitor mite population increase. **Experimental & Applied Acarology** 19, 181-188.

Calderón RA, Ortiz A, Aparisio B & Ruiz MT (2000). Varroa in Panama: detection, spread and prospects. **Bee World** 81, 126-128.

Calderón RA, Sommeijer MJ, De Ruijter A & Van Veen JW (2003). The reproductive ability of *Varroa destructor* in worker brood of Africanized and hybrid honey bees in Costa Rica. **Journal of Apicultural Research** 42, 65-67.

Calderone N (1999). Integrated pest management: varroa mites. **Bee Culture** 127, 20-25.

Calderone NW & Lin S (2003). Rapid determination of the numbers of *Varroa destructor*, a parasitic mite of the honey bee, *Apis mellifera*, on sticky-board collection devices. **Apidologie** 34, 11-17.

Calderone Nw & Spivak M (1997). Plant extracts used for the control of the parasitic mites *Varroa jacobsoni* (Acari: Varroidae) and *Acarapis woodi* (Acari: Tarsonemidae) in colonies of *Apis mellifera* (Hymenoptera: Apidae). **Journal of Economic Entomology** 90, 1080-1086.

Calis JNM (2001). **Parasite-host interactions between the *Varroa* mite and the honey bee**. Wageningen University, Wageningen, 144 pp.

Calis JNM, Boot WJ & Beetsma J (1997). Attractiveness of brood cells to *Varroa* mites in different honeybee races. **Apidologie** 28, 182.

Calis JNM, Boot WJ, Beetsma J, Van den Eijnde JHPM, De Ruijter A & Van der Steen JJM (1996). Trapping *Varroa jacobsoni* in drone brood combs of *Apis mellifera* in broodless colonies. **Apidologie** 27, 295.

Calis JNM, Boot WJ, Beetsma J, Van den Eijnde JHPM, De Ruijter A & Van der Steen JJM (1998). Control of varroa by combining trapping in honey bee worker brood with formic acid treatment of the capped brood outside the colony: putting knowledge on brood cell invasion into practice. **Journal of Apicultural Research** 37, 205-215.

Calis JNM, Boot WJ, Beetsma J, Van den Eijnde JHPM, De Ruijter A & Van der Steen JJM (1999a). Effective biotechnical control of varroa: applying knowledge on brood cell invasion to trap honey bee parasites in drone brood. **Journal of Apicultural Research** 38, 49-61.

Calis JNM, Fries I & Ryrie SC (1999b). Population modelling of *Varroa jacobsoni* Oud. **Apidologie** 30, 111-124.

Camazine, S (1986). Differentialreproduction of the mite *Varroa jacobsoni* (Mesostigmata: Varroidae) on Africanized and European honey bees (Hymenoptera: Apidae). **Annals of the Entomological Society of America** 79, 801-803.

Camazine S, Çakmak I, Cramp K, Finley J, Fisher J, Frazier M & Rozo A (1998). How healthy are commercially-produced U.S. honey bee queens? **American Bee Journal** 138, 677-680.

Chandler D, Sunderland KD, Ball BV & Davidson G (2001). Prospective biological control agents of *Varroa destructor*, an important pest of the European honeybee, *Apis mellifera*. **Biocontrol Science and Technology** 11, 429-448.

Colin ME, Vandame R, Jourdan P & Pasquale S (1997). Fluvalinate resistance of *Varroa jacobsoni* Oudemans (Acari: Varroidae) in Mediterranean apiaries of France. **Apidologie** 28, 375-384.

Collins AM & Pettis JS (2001). Effect of Varroa infestation on semen quality. **American Bee Journal** 141, 590-593.

Corrêa-Marques MH & De Jong D (1998). Uncapping of worker bee brood, a component of the hygienic behaviour of Africanized honey bees against the mite *Varroa jacobsoni* Oudemans. **Apidologie** 29, 283-289.

Corrêa-Marques MH, Cavicchio Issa MR & De Jong D (2000). Classification and quantification of damaged *Varroa jacobsoni* found in the debris of honey bee colonies as criteria for selection? **American Bee Journal** 140, 820-824.

Crane E (1978). The *Varroa* mite. **Bee World** 59, 164-167.

Crane E (1979). Fresh news on the Varroa mite. **Bee World** 60, 8.

Crane E (1983). **The Archaeology of Beekeeping.** International Bee Research Association, London, 360 pp.

Damblon F (1987). Miels de thym du maroc II. Étude palynologique des sources mellifĕres. **Al biruniya** 3, 51-75.

Danka RG & Villa JD (1994). Preliminary observations on the susceptibility of Africanized honey bees to American foulbrood. **Journal of Apicultural Research** 33, 243-245.

Danka RG, Villa JD, Harbo JR & Rinderer TE (1997). Initial evaluation of industry-contributed honey bees for resistance to *Varroa jacobsoni*. **American Bee Journal** 137, 221-222.

Davison S, Govan V, Leat N & Allsopp MH (1999). Bee diseases in South Africa I: EFB, AFB, chalkbrood and bee viruses. **South African Bee Journal** 71, 84-87.

DeGrandi-Hoffman G & Curry R (2004). A mathematical model of *Varroa* mite (*Varroa destructor* Anderson and Trueman) and honeybee (*Apis mellifera* L.) population dynamics. **International Journal of Acarology** 30, 259-274.

DeGrandi-Hoffman G, Page RE, Mrtin J & Fondrk MK (2002). Can the frequency of reduced *Varroa destructor* fecundity in honey bee (*Apis mellifera*) pupae be increased by selection? **Apidologie** 33, 563-570.

De Greef M, De Wael L & Van Laeres O (1994). The determination of the fluvalinate residues in Belgian honey and beeswax. **Apiacta** 29, 83-87.

De Guzman L, Rinderer TE, Delatte GT & Macchiavelli RE (1996). *Varroa jacobsoni* Oud. tolerance in selected stocks of *Apis mellifera*. **Apidologie** 27, 193-210.

De Guzman L, Rinderer TE, Stelzer A & Anderson D (1998). Congruence of RAPD and mitochondrial DNA markers in assessing *Varroa jacobsoni* genotypes. **Journal of Apicultural Research** 37, 49-51.

De Guzman LI, Rinderer TE, Stelzer JA, Beaman L, Delatte GT & Harper C (2002). Hygienic behaviour by honeybees from far-eastern Russia. **American Bee Journal** 142, 58-60.

De Jong D (1984). Current knowledge and open questions concerning reproduction in the honey bee mite *Varroa jacobsoni*. *In* **Advances in Invertebrate Reproduction 3**, Engels W (ed.). Elsevier Science Publishers, Amsterdam, pp. 547-552.

De Jong D (1987). Mites: varroa and other parasites of brood. *In* **Honey bee pests, predators and diseases (3rd edition)**, Morse R & Flottum K (eds.). AI Root, Medina, Ohio, pp. 282-327.

De Jong D (1996). Africanized honey bees in Brazil, forty years of adaptation and success. **Bee World** 77, 67-70.

De Jong D & De Jong PH (1983). Longevity of Africanized honeybees (Hymenoptera: Apidae) infested by *Varroa jacobsoni* (Parasitiformes: Varroidae). **Journal of Economic Entomology** 76, 766-768.

De Jong D & Soares AEE (1997). An isolated population of Italian bees that has survived *Varroa jacobsoni* infestation without treatment for over 12 years. **American Bee Journal** 137, 742-745.

De Jong D, Morse RA. & Eickwort GC (1982a). Mite pests of honey bees. **Annual Review of Entomology** 27, 229-252.

De Jong D, Gonçalves LS & Morse RA (1984). Dependence on climate of the virulence of *Varroa jacobsoni*. **Bee World** 65, 117-121.

Delaplane KS & Hood WM (1999). Economic threshold of *Varroa jacobsoni* Oud. in the Southeastern USA. **Apidologie** 39, 383-395.

Delfinado-Baker M, Rath W & Boecking O (1992). Phoretic bee mites and honeybee grooming behaviour. **International Journal of Acarology** 18, 315-322.

De Ruijter A (1987). Reproduction of *Varroa jacobsoni* during successive brood cycles of the honeybee. **Apidologie** 18, 321-326.

DFPT Statistics (2003). **Key Deciduous Fruit Statistics 2003**. Deciduous Fruit Producers Trust, Paarl, pp. 64.

Dietz A (1986). The geographical distribution and levels of infestation of the mite *Varroa jacobsoni* Oudemans (Parasitiformes: Varroidae) in honey bee colonies in Argentina. **American Bee Journal** 126, 49-51.

Dippenaar-Schoeman AS & Harvey MS (2000). A check list of the pseudoscorpions of South Africa (Arachnida: Pseudoscorpiones). **Koedoe** *4*3, 89-102.

Donovan BJ & Paul F (2005). Pseudoscorpions: the forgotten beneficials inside beehives and their potential for management for control of varroa and other arthropod pests. **Bee World** 86, 83-87.

Donzé G, Herrmann M, Bachofen B & Guerin PM (1996). Effect of mating frequency and brood cell infestation rate on the reproductive success of the honeybee parasite *Varroa jacobsoni*. **Ecological Entomology** 21, 17-26.

Donzé G, Fluri P & Imdorf A (1998). A look under the cap: the reproductive behaviour of varroa in the capped brood of the honey bee. **American Bee Journal** 138, 528-533.

Downey DL & Winston ML (2001). Honey bee colony mortality and productivity with single and dual infestations of parasitic mite species. **Apidologie** 32, 567-575.

Ducos de Lahitte J, Kefuss J, Ritter W & Vanpouke J (1998). Testing *Apis mellifera intermissa* from Tunisia for *Varroa jacobsoni* tolerance in France. **Apidologie** 29, 267-269.

Eguras M, Marcangeli J, Oppedisano M & Fernandez N (1995). Mortality and reproduction of *Varroa jacobsoni* in resistant colonies of bees (*Apis mellifera*) in Argentina. **Bee Science** 3, 174-178.

Eischen FA (1998a). Varroa's response to fluvalinate in the western US. **American Bee Journal** 138, 439-440.

Eischen FA (1998b). Trials (and tribulations) with formic acid for varroa control. **American Bee Journal** 138, 734-735.

Eischen FA & Wilson WT (1997). The effect of natural products smoke on *Varroa jacobsoni*. **American Bee Journal** 137, 222-223.

Eischen FA & Wilson WT (1998). The effect of natural products smoke on *Varroa jacobsoni*: an update. **American Bee Journal** 138, 293.

Ellis M (2000). Using powdered sugar to detect varroa. **Beekeeping and Honeybees Newsletter**. University of Nebraska Institute of Agriculture and Natural Resources.

Elzen PJ, Baxter JR, Spivak M & Wilson WT (1999). Amitraz resistance in varroa: new discovery in North America. **American Bee Journal** 139, 362.

Elzen PJ, Eischen FA, Baxter JR, Pettis J, Elzen GW & Wilson WT (1998). Fluvalinate resistance in *Varroa jacobsoni* from several geographical locations. **American Bee Journal** 138, 674-676.

Engels W, Gonçalves LS, Steiner J, Buriolla AH & Cavichio Issa MR (1986). Varroa-Befall von carnica-Völkern in Tropenklima. **Apidologie** 17, 203-216.

Erickson EH, Atmowidjojo AH & Hines L (1998). Can we produce varroa-tolerant honey bees in the United States? **American Bee Journal** 138, 828-832.

Erickson EH, Atmowidjojo AH & Hines LH (1999). Varroa-tolerant honey bees are a reality. **American Bee Journal** 139, 931-933.

Evans JD (2005). Beenome-mania: how will the honey bee genome project help beekeepers? **Bee World** 86, 25-26.

Fakhimzadeh K (2001). Effectiveness of confectioner sugar dusting to knock down *Varroa destructor* from adult honey bees in laboratory trials. **Apidologie** 32, 139-148.

Feldlaufer MF, Pettis JF, Kochansky JP & Shimanuki H (1997). A gel formulation of formic acid for the control of parasitic mites of honey bees. **American Bee Journal** 137, 661-663.

Fell R (1999). All about pollinating pumpkins and squash. **Bee Culture** 127, 23-25.

Fernández Muino MA & Simal Lozano J (1993). Gas chromatographic-mass spectrometric method for the simultaneous determination of amitraz, bromopropylate, coumaphos, cymiazole and fluvalinate residues in honey. **Analyst** 118, 1519 –1522.

Finley J, Camazine S & Frazier M (1996) The epidemic of honey bee colony losses during the 1995-1996 season. **American Bee Journal** 136, 805-808.

Fletcher DJC (1978). The African bees, *Apis mellifera adansonii*, in Africa. **Annual Review of Entomology** 23, 151-171.

Flores JM, Ruiz JA, Ruz JM, Puerta F & Bustos M (2001). Hygienic behaviour of *Apis mellifera iberica* against brood cells artificially infested with varroa. **Journal of Apicultural Research** 40, 29-34.

Free JB (1993). **Insect pollination of crops**. Academic Press, London, 684 pp.

Fries I (1989). Short-interval treatments with formic acid for control of *Varroa jacobsoni* in honey bee (*Apis mellifera*) colonies in cold climates. **Swedish Journal Agricultural Research** 19, 213-216.

Fries I (1997). Organic control of varroa. *In* **Varroa! Fight the mite**, Munn P & Jones R (eds.). International Bee Research Association, Cardiff, pp.16-21.

Fries I (2001). Honey bees and *Varroa destructor* – live and let die. **Apidologie** 32, 479-480.

Fries I & Rosenkranz P (1996). Number of reproductive cycles of *Varroa jacobsoni* in honeybee (*Apis mellifera*) colonies. **Experimental & Applied Acarology** 20, 103-112.

Fries I, Aarhus A, Hansen H & Korpela S (1991). Comparison of diagnostic methods for detection of low infestation levels of *Varroa jacobsoni* in honey bee (*Apis mellifera*) colonies. **Experimental & Applied Acarology** 10, 279-287.

Fries I, Camazine S. & Sneyd J (1994). Population dynamics of *Varroa jacobsoni* - a model and a review. **Bee World** 75, 5-27.

Fries I, Huazhen W, Wei S, & Shu Jin C (1996). Grooming behaviour and damaged mites (*Varroa jacobsoni*) in *Apis mellifera cerana* and *Apis mellifera ligustica*. **Apidologie** 27, 3-11.

Fries I, Wallner K & Rosenkranz P (1998). Effects on *Varroa jacobsoni* from acaricides in beeswax. **Journal of Apicultural Research** 37, 85-90.

Fuchs S (1990). Preference for drone brood cells in *Varroa jacobsoni* Oud. in colonies of *Apis mellifera carnica*. **Apidologie** 21, 193-199.

Fuchs S & Langenbach K (1989). Multiple infestation of *Apis mellifera* L. brood cells and reproduction in *Varroa jacobsoni* Oud. **Apidologie** 20, 257-266.

Garg GR & Sharma OP (1988). Studies to establish the effective dose of precipitated sulphur against *Tropilaelaps clareae* Delfinado and Baker (Laelaptidae: Acarina). **American Bee Journal** 128, 122-123.

Garrido C & Rosenkranz P (2003). The reproductive program of female *Varroa destructor* mites is triggered by its host, *Apis mellifera*. **Experimental & Applied Acarology** 31, 269-273.

Garrido C, Rosenkranz P, Stürmer M, Rübsam R & Büning J (2000). Toluidine blue staining as a rapid measure of oocyte growth and fertility in *Varroa jacobsoni* Oud. **Apidologie** 31, 559-566.

Garrido C, Paxton RJ & Rosenkranz P (2003). Reproduction in *Varroa* mites: triggered by the host or parasite traits. **Apidologie** 34, 481-482.

Garcia-Fernández P, Benitez Rodriguez R & Orantes-Bermejo FJ (1995). Influence du climat sur le développement de la population de *Varroa jacobsoni* Oud. dans des colonies d'A*pis mellifera iberica* (Goetze) dans le sud de l'Espagne. **Apidologie** 26, 371-380.

Gerson U, Mozes-Koch R, & Cohen E (1991). Enzyme levels used to monitor pesticide resistance in *Varroa jacobsoni*. **Journal of Apicultural Research** 30, 17-20.

Gilliam M, Taber S & Richardson GV (1983). Hygienic behaviour of honey bees in relation to chalkbrood disease. **Apidologie** 14, 29-39.

Gomez Pajuelo A (1988). Situation of the varroatosis in Spain and Portugal. *In* **Present status of varroatosis in Europe and progress in the Varroa mite control**, Cavalloro R (ed.), Balkema, Rotterdam, 41-43.

Goodwin M & Van Eaton C (2001). **Control of Varroa: A guide for New Zealand Beekeepers**. New Zealand Ministry of Agriculture and Forestry, Wellington, 120 pp.

Grobov OF (1977).Varroasis in bees. In **Varroasis: a honey bee disease**. Apimondia Publishing House, Bucharest, Romania, pp. 46-91.

Guerra JCV, Gonçalves LS & De Jong D (2000). Africanized honey bees (*Apis mellifera* L.) are more efficient at removing worker brood artificially infested with the parasitic mite *Varroa jacobsoni* Oudemans than are Italian bees or Italian/Africanized hybrids. **Genetics and Molecular Biology** 23, 89-92.

Gufler H & Wallner K (1995). Apistanresistente varroa-milben auch in rüdtirol. **Deutches Bienen Journal** 3, 245-246.

Guzman-Novoa E, Sanchez A, Page RE & Garcia T (1996). Susceptibility of European and Africanized honeybees (*Apis mellifera* L.) and their hybrids to *Varroa jacobsoni* Oud. **Apidologie** 27, 93-103.

Guzman-Novoa E, Vandame R & Arechavaleta ME (1999). Susceptibility of European and Africanized honey bees (*Apis mellifera* L.) to *Varroa jacobsoni* Oud. in Mexico. **Apidologie** 30, 71-77.

Hansen H & Guldborg M (1988). Residues in honey and wax after treatment of bee colonies with formic acid. **Tidsskrift for Planteavl 92, 7-10.**

Hansen H & Petersen JH (1988). Residues in honey and wax after treatment of honey bee colonies with bromopropylate. **Tidsskrift for Planteavl** 92, 1-6.

Harbo JR (1996). Evaluating colonies of honeybees for resistance to *Varroa jacobsoni*. **Bee Science**, 4, 100-105.

Harbo J & Harris J (1999). Selecting honeybees for resistance to *Varroa jacobsoni*. **Apidologie** 30, 183-196.

Harbo J & Harris J (2001). Resistance to *Varroa destructor* (Mesostigmata: Varroidae) when mite-resistant queen honey bees (Hymenoptera: Apidae) were free-mated with unselected drones. **Journal of Economic Entomology** 94, 1319-1323.

Harbo JR & Harris JW (2005). Suppressed mite reproduction explained by the behaviour of adult bees. **Journal of Apicultural Research** 44, 21-23.

Harbo JR & Hoopingarner RA (1997). Honey bees (Hymenoptera: Apidae) in the United States that express resistance to *Varroa jacobsoni* (Mesostigmata: Varroidae). **Journal of Economic Entomology** 90, 893-898.

Harman A (2000). NZ finds varroa. **Bee Culture** 128, 39-41.

Harris JW & Harbo JR (1998). Low sperm counts and delayed oviposition of mites in colonies of honeybees that are resistant to *Varroa jacobsoni*. **American Bee Journal** 138, 296.

Harris JW & Harbo JR (1999). Low sperm counts and reduced fecundity of mites in colonies of honey bees (Hymenoptera: Apidae) resistant to *Varroa jacobsoni* (Mesostigmata: Varroidae). **Journal of Economic Entomology** 92, 83-90.

Harris JW & Harbo JR (2000). Changes in reproduction of *Varroa destructor* after honey bee queens were exchanged between resistant and susceptible colonies. **Apidologie** 31, 689-699.

Harris JW, Harbo JR, Villa JD & Danka RG (2003). Variable population growth of *Varroa destructor* (Mesostigmata: Varroidae) in colonies of honey bees (Hymenoptera: Apidae) during a 10-year period. **Environmental Entomology** 32, 1305-1312.

Hartwig A (1994). An epidemic of Varroosis in Poland 1980-1993. *In* **New Perspectives on Varroa**, Matheson A (ed.), International Bee Research Association, Cardiff, UK, pp. 127-128.

Haupt W, Ribbeck R, Will R & Hertzsch K (1996). Erfahrungen mit der Anwendung von Bayvarol strips bei Bienenvölkern in Magazinen und Hinterbehandlungsbeuten zur Bekämping der Varroatose unter Praxisbedingungen. **Berlin und München Tierärztl. Wschr**., 109, 232-238.

Henderson CE, Steiner J & Alexander B (1986). *Varroa jacobsoni* life cycle. **American Bee Journal** 126, 117-119.

Hepburn HR & Crewe RM (1991). Portrait of the Cape honeybee, *Apis mellifera capensis*. **Apidologie** 22, 567-580.

Hepburn HR & Jacot Guillarmod A (1991). The Cape honeybee and the fynbos biome. **South African Journal of Science** 87, 70-73.

Hepburn HR & Radloff SE (1998). **Honeybees of Africa**. Springer, Berlin, 367 pp.

Higes PM, Suàrez RM & Llorente J (1997). Comparative field trials of *Varroa* mite control with different components of essential oils (thymol, menthol, camphor). **Research Revue of Parasitology** 57, 21-54.

Hillesheim E, Ritter W & Bassand D (1996). First data on the resistance mechanisms of *Varroa jacobsoni* (Oud.) against tau-fluvalinate. **Experimental & Applied Acarology** 20, 283-296.

Hoppe H, Ritter W & Stephen EWC (1989). The control of parasitic bee mites: *Varroa jacobsoni, Acarapis woodi* and *Tropilaelaps clareae* with formic acid. **American Bee Journal** 129, 739-742.

Horr B (1998). Biological control of varroa mites without chemicals. **American Bee Journal** 138, 801-804.

Hung ACF, Shimanuki H & Knox DA (1995). Bee parasitic mite syndrome (ii): the role of varroa and viruses. **American Bee Journal** 135,702-704.

Hunt GJ (1998). The war against varroa: how are we doing? **American Bee Journal** 138, 372-374.

Ibrahim A & Spivak M (2004). The relationship between suppression of mite reproduction (SMR) and hygienic behaviour. **American Bee Journal** 144, 406.

Ifantidis MD (1983). Ontogenesis of the mite *Varroa jacobsoni* in worker and drone honeybee brood cells. **Journal of Apicultural Research** 22, 200-206.

Ifantidis MD (1988). Some aspects of the process of *Varroa jacobsoni* mite entrance into honey bee (*Apis mellifera*) brood cells. **Apidologie** 19, 387-396.

Ifantidis MD (1990). Re-examination of reproduction parameters of the mite *Varroa jacobsoni* Oudemans. *In* **Proceedings of the internal symposium on recent research on bee pathology**, Ritter W, Van Laere O, Jacobs F & De Wael L (eds.). Janssen Pharmaceutica, Beerse, Belguim, pp. 20-26.

Ifantidis MD & Rosenkranz P (1988). Reproduktion der bienenmilbe *Varroa jacobsoni* (Acarina: Varroidae). **Entomologie Generalis** 14, 111-122.

Imdorf A, Bogdanov S, Kilchenmann V & Maquelin C (1995). Apilife Var: a new varroacide with thymol as the main ingredient. **Bee World** 76, 77-83.

Imdorf A, Charriére J-D, Maquelin C, Kilchenmann V & Bachofen B (1996). Alternative varroa control. **American Bee Journal** 136, 189-193.

Jandricic SE & Otis GW (2003). The potential for using male selection in breeding honey bees resistant to *Varroa destructor*. **Bee World** 84, 155-164.

Janmaat AF & Winston ML (2000). Removal of *Varroa jacobsoni* infested brood in honey bee colonies with differing pollen stores. **Apidologie** 31, 377-385.

Jay S (1962). Prepupal and pupal ecdysis of the honeybee. **Journal of Apicultural Research** 1, 14-18.

Johannsmeier MF (2001). Beekeeping History. *In* **Beekeeping in South Africa (third edition)**, Johannsmeier MF (ed.). Plant Protection Research Institute handbook no.14, Pretoria, pp. 1-8.

Johannsmeier MF & Mostert AM (2001). Crop Pollination. *In* **Beekeeping in South Africa (third edition)**, Johannsmeier MF (ed.). Plant Protection Research Institute handbook no.14, Pretoria, pp. 235-245.

Johns J, Allsopp MH & Davison (2006). Varroa mite transmission of honeybee viruses results in pupal mortality. In preparation.

Johnson SD (1992). Plant-Animal Relationships. *In* **The Ecology of Fynbos,** Cowling RM (ed.), Oxford University Press, Cape Town, 411 pp.

Judson MLI (1990). Re-description of the bee-associate *Ellingsenius fulleri* (Hewitt and Godfrey) (Arachnida, Chelonethi, Cheliferidae) with new records from Africa, Europe and the middle east. **Journal of Natural History** 24, 1303-1310.

Kanga LHB, Jones WA & James RR (2003). Field trials using the fungal pathogen, *Metarhizium anisopliae* (Deuteromyces: Hyphomycetes) to control the ectoparasitic mite, *Varroa destructor* (Acari: Varroidae) in honey bee, *Apis mellifera* (Hymenoptera: Apidae) colonies. **Journal of Economic Entomology** 96, 1091-1099.

Kefuss JA (1995). Honey bee hygienic behaviour: France, Tunisia and Chile. **Apidologie** 26, 325-327.

Kirsch R & Rosenkranz P (1998). Population dynamics of honey bees, honey bee brood and *Varroa jacobsoni* mites in untreated colonies in Uruguay. **Apidologie** 29, 279-281.

Koeniger G & Würkner W (1992). Die Kap-Honigbienen (*Apis mellifera capensis*): Natürliche Verbreitung und die Schwierigkeiten der Haltung unter unseren klimatischen Bedingungen. **Die Biene** 128, 583-588.

Koeniger N (1985). Varroa's natural adaptation to *Apis mellifera*. **Bee World** 66, 125-127.

Koeniger N, Koeniger G & Wijayagunasekara NHP (1981). Beobachtungen über die anpassung von *Varroa jacobsoni* an ihren natürlichen Wirt *Apis cerana* in Sri Lanka. **Apidologie** 12, 37-40.

Kokkinis M & Liakos V (2004). Population dynamics of *Varroa destructor* in colonies of *Apis mellifera macedonica* in Greece. **Journal of Apicultural Research** 43, 150-154.

Korpela S, Aarhus A, Fries I & Hansen H (1992). *Varroa jacobsoni* Oud. in cold climates: population growth, winter mortality and influence on the survival of the honey bee. **Journal of Apicultural Research** 31, 157-164.

Kovac H & Crailsheim K (1988). Lifespan of *Apis mellifera carnica* Pollm. infested by *Varroa jacobsoni* Oud. in relation to season and extent of infestation. **Journal of Apicultural Research** 27, 230-238.

Kralj J & Fuchs S (2002). Flight duration of worker bees (*Apis mellifera*) infested with *Varroa destructor*. **Apidologie** 33, 490-491.

Kraus B & Hunt G (1995). Differentiation of *Varroa jacobsoni* Oud. populations by random amplification of polymorphic DNA (RAPD). **Apidologie** 26, 283-290.

Kraus B (1994). Factors influencing host choice of the honey bee parasite *Varroa jacobsoni* Oud. **Experimental & Applied Acarology** 18, 435-443.

Kraus B & Page RE (1995a). Population growth of *Varroa jacobsoni* Oud. in Mediterranean climates in California. **Apidologie** 26, 149-157.

Kraus B & Page RE (1995b). Effect of *Varroa jacobsoni* (Mesostigmata: Varroidae) on feral *Apis mellifera* (Hymenoptera: Apidae) in California. **Environmental Entomology** 24, 1473-1480.

Kraus B, Koeniger N & Fuchs S (1994). Screening of substances for their effect on *Varroa jacobsoni*: attractiveness, repellency, toxicity and masking effects of ethereal oils. **Journal of Apicultural Research** 33, 34-43.

Krieger KJ (1995). **Untersuchungen zur chemotherapeutischen Bekämpfung der parasitären Honigbienenmilbe *Varroa jacobsonii* Oud.** Bayer AG Internal Report.

Kulinčević JM, Rinderer TE & Urošević DJ (1988). Seasonality and colony variation of reproducing and non-reproducing *Varroa jacobsoni* females in Western honey bee (*Apis mellifera*) worker brood. **Apidologie** 19, 173-179.

Kulinčević JM, Rinderer TE, Mladjan VJ & Buco SM (1992). Five years of bi-directional genetic selection for honey bees resistant and susceptible to *Varroa jacobsoni*. **Apidologie** 23, 443-452.

Kustermann T (1990). Populationsstruktur der *Varroa*-milbe. **Deutsches Imker-Journal** 1, 436-437.

Le Conte Y, Arnold D, Trouiller J, Masson C, Chappe B & Ourisson G (1989). Attraction of the parasitic mite *Varroa* to the drone larvae of honey bees by simple aliphatic esters. **Science** 245, 638-639.

Liebig G, Schlipf U, Fremuth W & Ludwig W (1984). Ergebnisse der Untersuchungen uber die Befallsentwicklung der *Varroa*-milbe in Stuttgart-Hohenhein 1983. **Allgemeine Deutsche Imkerzeitung** 18, 185-191.

Lodesani M (1996). Variabilità dell' efficacia terapeutica ottenuta con trattamento di Perizin. **L' ape Nostra Amica** 18, 5-9.

Lodesani M, Pellacani A, Bergomi S, Carpana E, Rabitti T & Lasagni P (1992). Residue determination for some products used against *Varroa* infestation in bees. **Apidologie** 23, 257-272.

Lodesani M, Colombo M & Spreafico M (1995). Ineffectiveness of apistan treatment against the mite *Varroa jacobsoni* Oud. in several districts of Lombardy (Italy). **Apidologie** 26, 67-72.

Lodesani M, Vecchi MA, Tommasini S & Bigliarde M (1996). Study on different kinds of damage to *Varroa jacobsoni* in *Apis mellifera ligustica* colonies. **Journal of Apicultural Research** 35, 49-56.

Lodesani M, Crailsheim K & Moritz RFA (2002). Effect of some characters on the population growth of mite *Varroa jacobsoni* in *Apis mellifera* L. colonies and results of bi-directional selection. **Journal of Applied Entomology** 126, 130-137.

Loglio G & Plebani G (1992). Valutazione dell'efficacia dell' Apistan. **Apic. Mod.** 83, 95-98.

Loper GM (1995). A documented loss of feral bees due to mite infestations in S. Arizona. **American Bee Journal** 135, 823-824.

Loper GM (1996). Nesting sites and the characterization of feral honey bees in the Sonoran desert of Arizona. **Bee Science** 4, 71-77.

Loper G (1997). Over-winter losses of feral honey bee colonies in southern Arizona, 1992-1997. **American Bee Journal** 137, 446.

Macedo PA, Wu J & Ellis MD (2002). Using inert dusts to detect and assess varroa infestations in honey bee colonies. **Journal of Apicultural Research** 40, 3-7.

Marcangeli JA, Eguaras MJ & Fernandez NA (1992). Reproduction of *Varroa jacobsoni* (Acari: Mesostigmata: Varroidae) in temperate climates of Argentina. **Apidologie** 23, 57-50.

Martin SJ (1994). Ontogenesis of the mite *Varroa jacobsoni* Oud. in worker brood of the honeybee *Apis mellifera* L. under natural conditions. **Experimental and Applied Acarology** 18, 87-100.

Martin SJ (1995a). Reproduction of *Varroa jacobsoni* in cells of *Apis mellifera* containing one or more mother mites and the distribution of these cells. **Journal of Apicultural Research** 34, 187-196.

Martin SJ (1995b). Ontogenesis of the mite *Varroa jacobsoni* Oud. in drone brood of the honeybee *Apis mellifera* L. under natural conditions. **Experimental & Applied Acarology** 19, 199-210.

Martin SJ (1997a). Life and death of varroa. *In* **Varroa! Fight the mite,** Munn P & Jones R (eds.). International Bee Research Association, Cardiff, pp. 3-10.

Martin SJ (1997b). *Varroa jacobsoni* population biology research in the UK. **American Bee Journal** 137, 382-385.

Martin SJ (1998). A population dynamic model of the mite *Varroa jacobsoni*. **Ecological Modelling** 109, 267-281.

Martin SJ (2001). The role of *Varroa* and viral pathogens in the collapse of honey bee colonies: a modelling approach. **Journal of Applied Ecology** 38, 1082-1093.

Martin SJ & Kemp D (1997). Average number of reproductive cycles performed by *Varroa jacobsoni* in honey bee (*Apis mellifera*) colonies. **Ecological Entomology** 21, 17-26.

Martin SJ & Kryger P (2002). Reproduction of *Varroa destructor* in South African honeybees: does cell space influence *Varroa* male survivorship? **Apidologie** 33, 51-61.

Martin SJ, Holland K & Murray M (1997). Non-reproduction in the honeybee mite *Varroa jacobsoni*. **Experimental and Applied Acarology** 21, 539-549.

Martin SJ, Hogarth A, Van Breda J & Perrett J (1998). A scientific note on *Varroa jacobsoni* Oudemans and the collapse of *Apis mellifera* colonies in the United Kingdom. **Apidologie** 29, 369-370.

Martin SJ. Wossler T & Kryger P (2002) Usurpation of African *Apis mellifera scutellata* colonies by parasitic *Apis mellifera capensis* workers. **Apidologie** 33, 215-232.

Matheson A (1993). World bee health report. **Bee World** 74, 176-212.

Matheson A (1995). First documented findings of *Varroa jacobsoni* outside its resumed natural range. **Apiacta** 30, 1-8.

Matheson A (1996). World bee health update 1996. **Bee World** 77, 451-54.

Matheson A (2000). Varroa discovered in New Zealand. **Bee World** 81, 43-44.

Medina LM (1998). Frequency and infestation levels of the mite *Varroa jacobsoni* Oud. in managed honey bee (*Apis mellifera* L.) colonies in Yucatan, Mexico. **American Bee Journal** 138, 125-127.

Medina LM & Martin SJ (1999). A comparative study of *Varroa jacobsoni* reproduction in worker cells of honey bees (*Apis mellifera*) in England and Africanized bees in Yucatan, Mexico. **Experimental & Applied Acarology** 23, 659-667.

Medina LM, Martin SJ, Espinosa-Montaňo L & Ratnieks FLW (2002). Reproduction of *Varroa destructor* in worker brood of Africanized honey bees (*Apis mellifera*). **Experimental & Applied Acarology** 26, 1-10.

Medina LM & Mejia EV (1999). The presence of *Varroa jacobsoni* mite and *Ascosphaera apis* fungi in collapsing and normal honey bee (*Apis mellifera* L.) colonies in Yucatan, Mexico. **American Bee Journal** 139, 794-796.

Message D & Gonçalves LS (1995). Effect of size of worker brood cells of Africanized honey bees on infestation and reproduction of the ectoparasitic mite *Varroa jacobsoni* Oud. **Apidologie** 26, 381-386.

Mikawa F (1986). A study on the extermination of *Varroa jacobsoni*. *In* **Proceedings of the XXXth International Congress of Apiculture**, International Federation of Beekeepers' Associations (eds.), Apimondia, Bucharest, pp. 178-179.

Milani N (1995). The resistance of *Varroa jacobsoni* Oud. to pyrethroids: a laboratory assay. **Apidologie** 26, 415-429.

Milani N (1999). The resistance of *Varroa jacobsoni* Oud. to acaracides. **Apidologie** 30, 229-234.

Monaco R (1997). Development of resistance against *Varroa jacobsoni* Oudemans in a natural population of *Apis mellifera ligustica* Spinola. **American Bee Journal** 137, 140-142.

Moosbeckhofer R (1992). Beobachtungen zum Auftreten beschädigter Varroamilben im natürlichen Totenfall bei Völkern von *Apis mellifera carnica*. **Apidologie** 23, 523-531.

Moosbeckhofer R (1996). Apistanresistente Varroamilben in Ősterreich entdeckt. **Bienenvater** 117, 372-373.

Moosbeckhofer R (1997). Observations on reproduction rate of *Varroa jacobsoni* and the occurrence of mutilated mites in *Apis mellifera carnica* colonies. **Apidologie** 28, 193-195.

Moosbeckhofer R, Fabsicz M & Kohlich A (1988). Untersuchungen über die Abhängigkeit der nachkommensrate von *Varroa jacobsoni* Oud. vom Befallsgrad der Bienenvölker. **Apidologie** 19, 181-208.

Moosbeckhofer R, Pechhacker H & Kohlich A (1997). Test of different methods of long term formic acid treatments against *Varroa jacobsoni* **Apidologie** 28, 195-196.

Moretto G, Gonçalves LS, De Jong D & Bichuette MZ (1991). The effects of climate and bee race on *Varroa jacobsoni* Oud. infestations in Brazil. **Apidologie** 22, 197-203.

Moretto G, Gonçalves LS & De Jong D (1993). Heritability of Africanized and European honey bee defensive behaviour against the mite *Varroa jacobsoni*. **Revue Brasilia Genetica** 16, 71-77.

Moretto G, Pilatti A, Cassini FL, Dellatorre SF, Bonetto LC & Puttkammer E (1995). Levels of infestation by the mite *Varroa jacobsoni* in colonies of *Apis mellifera* honeybees in the state of Santa Catarina, Brazil. **Apiacta** 30, 9-12.

Moretto G, Gonçalves LS & De Jong D (1997). Relationship between food availability and the reproductive ability of the mite *Varroa jacobsoni* in Africanized bee colonies. **American Bee Journal** 137, 67-69.

Moritz RFA (1981). Altersabhängige Empfindlichkeit von *Varroa jacobsoni* (Oudemans) gegen K-79 (Chlordimeformhydrochlorid). *In* **Diagnose und Therapie der Varroatose**, Apimondia, Bucharest, pp. 62-68.

Moritz RFA (1985) Heritability of the postcapping stage in *Apis mellifera* and its relation to varroatosis resistance. **Journal of Heredity** 76, 267-270.

Moritz RFA & Hänel H (1984). Restricted development of the parasitic mite *Varroa jacobsoni* Oud. in the Cape Honeybee *Apis mellifera capensis* Esch. **Zeitschrift angew Entomologie** 97, 91-94.

Moritz RFA & Mautz D (1990). Development of *Varroa jacobsoni* in colonies of *Apis mellifera capensis* and *Apis mellifera carnica*. **Apidologie** 21, 53-58.

Moritz RFA & Jordan M (1992). Selection of resistance against *Varroa jacobsoni* across caste and sex in the honeybee (*Apis mellifera* L., Hymenoptera: Apidae). **Experimental & Applied Acarology** 16, 345-353.

Morse RA & Calderone NW (2000). The value of honey bees as pollinators of U.S. crops in 2000. **Bee Culture** 128(3), 1-16 (insert).

Murthy VA & Venkataramanan R (1985). Contribution to the biology of the pseudoscorpion *Ellingsenius indicus* Chamberlin. **Indian Bee Journal** 47, 34-35.

Murthy VA & Venkataramanan R (1986). *Ellingsenius indicus* (Arachnida: Chelonethi) as a tool to the assessment of the settling nature of honeybee (*Apis cerana indica*) colony, in a new habitat. **Indian Bee Journal** 48, 54-55.

Mutinelli F, Baggio A, Capolongo F, Piro R, Prandin L & Biasson L (1997). A scientific note on oxalic acid by topical application for the control of varroosis. **Apidologie** 28, 461-462.

Needham GR (1988). Status report on *Varroa jacobsoni*. **American Bee Journal** 128, 106-110.

Neumann P & Hepburn HR (2002). Behavioural basis for social parasitism of Cape honeybees (*Apis mellifera capensis*). **Apidologie** 33, 65-192.

Onions GW (1912). South African 'fertile worker bees'. **South African Agricultural Journal** 1,720-728.

Österlund E (1998). Varroa doesn't kill bees, but virus does! **American Bee Journal** 138, 377-381.

Otten C (1991). Factors and effects of a different distribution of *Varroa jacobsoni* between adult bees and bee brood. **Apidologie** 22, 465-467.

Otten C & Fuchs S (1988). Individual differences in *Varroa jacobsoni* of preference for drone larvae to worker bee larvae. *In* **European Research on Varroatosis Control**, Cavalloro R (ed.). A.A. Balkema, Rotterdam, pp. 69-71.

Otten C & Fuchs S (1990). Seasonal variations in the reproductive behaviour of *Varroa jacobsoni* in colonies of *Apis mellifera carnica, A.m.ligustica* and *A.m.mellifera*. **Apidologie** 21, 367-368.

Otteni M & Ritter W (1998). Susceptibility of bee pupae for virus infections. **Apidologie** 29, 274-275.

Page RE (1998). Varroa mite impacts Africanized bee spread and beekeeping. **California Agriculture** 52, 9-12.

Pechhacker H (1998). Paarungskontrolle und Belegstellen. **Allegemeine Deutsche Imkerzeitung** 32, 14-15.

Peng YS, Fang Y, Xu S & Ge L (1987). The resistance mechanism of the Asian honey bee, *Apis cerana* Fabr., to an ectoparasitic mite, *Varroa jacobsoni* Oudemans. **Journal of Invertebrate Pathology** 49, 54-60.

Pohl F & Ritter W (1997). New results of two virus diseases (APV,SBV) of the honeybee. **Apidologie** 28, 174-175.

Radtke J (1997) Zur Frage individueller Bevorzugung von Drohnen- bzw. Arbeiterbrut durch *Varroa jacobsoni* Oud. **Apidologie** 28, 188-190.

Rath W (1991). Laboratory culture of the mites *Varroa jacobsoni* and *Tropilaelaps clareae*. **Experimental & Applied Acarology** 10, 289-293.

Rath W & Drescher W (1990). Response of *Apis cerana* Fabr. towards brood infested with *Varroa jacobsoni* Oud. and infestation rate of of colonies in Thailand. **Apidologie** 21, 311-321.

Rehm SM & Ritter W (1989). Sequence of the sexes of the offspring of *Varroa jacobsoni* and the resulting consequences for the calculation of the development period. **Apidologie** 20, 339-343.

Rinderer TE, De Guzman LI, Kulinčević JM, Delatte GT, Beaman LD & Buco SM (1993). The breeding, importing, testing and general characteristics of Yugoslavian honey bees bred for resistance to *Varroa jacobsoni*. **American Bee Journal** 133, 197-200.

Rinderer TE, Kuznetsov VN, Danka RG & Delatte GT (1997). An importation of potentially varroa-resistant honey bees from far-eastern Russia. **American Bee Journal** 137, 787-789.

Rinderer TE, De Guzman LI, Lancaster VA, Delatte GT & Stelzer JA (1999). Varroa in the mating yard: I. The effects of *Varroa jacobsoni* and Apistan on drone honey bees. **American Bee Journal** 139, 134-139.

Rinderer TE, De Guzman LI, Delatte GT, Stelzer JA, Lancaster VA, Kuznetsov V & Beaman L (2001). Resistance to the parasitic mite *Varroa destructor* in honey bees from far-eastern Russia. **Apidologie** 32, 381-394.

Ritter W (1984). Neuester Stand der diagnostischen und therapeutischen Massnahmen zur Bekämpfung der Varroatose. **Tierärztliche Umschau** 39, 122-127.

Ritter W (1990). Development of the *Varroa* mite populations in treated and untreated colonies in Tunisia. **Apidologie** 21, 368-370.

Ritter W & De Jong D (1984). Reproduction of *Varroa jacobsoni* Oud. in Europe, the Middle East and tropical South America. **Zeitschrift angew Entomologie** 98, 55-57.

Ritter W, Leclercq E & Koch W (1984). Observations on *Varroa jacobsoni* mite populations in infested honeybee colonies. **Apidologie** 15, 43-62.

Ritter W, Michel P, Bartholdi M & Schwendemann A (1990). Development of tolerance to *Varroa jacobsoni* in bee colonies in Tunisia. *In* **Proceedings of the International Symposium on Recent Research in Bee Pathology**, Ritter W (ed.). Apimondia Publishing House, Bucharest, pp. 54-59.

Robinson W, Nowogrodski R & Morse R (1989). The value of honey bees as pollinators of U.S. crops. **American Bee Journal** 129, 411-423, 477-487.

Rodger J & Balkwill K (2002). African pollination studies: where are the gaps? **African Pollinators Initiative (API) Workshop**, Nairobi, 18th – 22nd February.

Rosenkranz P (1999). Honey bee (*Apis mellifera* L.) tolerance to *Varroa jacobsoni* Oud. in South America. **Apidologie** 30, 159-172.

Rosenkranz P & Bartalszky H (1996). Reproduction of *Varroa* females after long broodless periods of the honey bee colony during summer. **Apidologie** 27, 288-290.

Rosenkranz P & Engels W (1994). Infertility of *Varroa jacobsoni* females after invasion into *Apis mellifera* worker brood as a tolerance factor against varroatosis. **Apidologie** 25, 402-411.

Rosenkranz P & Stürmer M (1992). Ernährungsabhängige fertilität der *Varroa*-weibchen in arbeiterinnenbrut von *Apis mellifera carnica* und *Apis mellifera capensis*. **Ann Univ Mariae Curie Sklodowska** 47, 55-60.

Rosenkranz P, Tewarson NC & Engels W (1984). Optimal host selection by reproductive female *Varroa jacobsoni*. *In* **Advances in Invertebrate Reproduction 3**, Engels W (ed.), Elsevier Science Publishers, Amsterdam, pp. 628.

Rosenkranz P, Rachinsky A, Strambi A, Strambi C & Röstorf P (1990). Juvenile hormone titer in capped worker brood of *Apis mellifera* and reproduction in the bee mite *Varroa jacobsoni*. **General and Comparative Endocrinology** 78, 189-193.

Rosenkranz P, Tewarson NC, Singh A & Engels W (1993). Differential hygienic behaviour towards *Varroa jacobsoni* in capped worker brood of *Apis cerana* depends on alien scent adhering to the mites. **Journal of Apicultural Research** 32, 89-93.

Rosenkranz P, Fries I, Boecking O & Stürmer M (1997). Damaged *Varroa* mites in the debris of honey bee (*Apis mellifera* L.) colonies with and without hatching brood. **Apidologie** 28, 427-437.

Rothenbuhler WC (1964). Behaviour genetics of nest cleaning in honey bees. IV. Response of F1 and backcross generations to disease-killed brood. **American Zoologist** 4, 111-123.

Ruttner F (1983). Varroatosis in honeybees: extent of infestations and effects. *In* ***Varroa jacobsoni* Oud. affecting honey bees: present status and needs.** A.A. Balkema, Rotterdam, pp. 7-13.

Ruttner F (1988). **Biogeography and Taxonomy of Honeybees**. Springer-Verlag, Berlin. 387 pp.

Ruttner F (1991). Auf dem wege zu einer varroatoleranten carnica. **Allgemeine Deutsche Imkerzeitung** 25, 10-15.

Ruttner F & Hänel H (1992). Active defence against *Varroa* mites in a carnolian strain of honeybee (*Apis mellifera carnica* Pollmann). **Apidologie** 23, 173-187.

Ruttner F, Marx H & Marx G (1984). Beobachten über eine möglische anpassung von *Varroa jacobsoni* in *Apis mellifera* L. **Apidologie** 15, 43-62.

SAS Institute, Inc. (1999). **SAS/Stat user's guide, version 8, 1st printing, volume 2**. SAS Institute Inc., SAS Campus Drive, Cary, North Carolina.

Shapiro SS & Wilk MB (1965). An analysis of variance test for normality (complete samples), **Biometrika** 52, 591-611.

Siuda M & Wilde J (2000). Variability of the capped brood developmental stage in a honey bee line selected for a short post-capping period. **Apidologie** 31, 597-663.

Snedecor GW & Cochran WG (1967). **Statistical methods, 6th Edition**, Iowa State University Press, Ames, Iowa USA.

Sammatoro D (1997). Report on parasitic bee mites and diseases associations. **American Bee Journal** 137, 301-302.

Sammatoro D, Degrandi-Hoffman G, Needham G & Wardell G (1998). Some volatile plant oils as potential control agents for varroa mites (Acari: Varroidae) in honey bee colonies (Hymenoptera: Apidae). **American Bee Journal** 138, 681-685.

Schatton-Gadelmayer K & Engels W (1988). Blood proteins and body weight of newly emerged worker honey bees with different levels of parasitisation of brood mites. **Entomologia Generalis** 14, 93-101.

Schmidt JO (1999). Attractant or pheromone: the case of Nasonov secretion and honeybee swarms. **Journal of Chemical Ecology** 25, 2051-2056.

Schneider P & Drescher W (1987). The influence of *Varroa jacobsoni O*ud. on weight, development of weight and hyphopharyngeal glands, and longevity of *Apis mellifera* L. **Apidologie** 18, 101-110.

Schousboe C (1986). The duration of sealed cell stage in worker honeybee brood (*Apis mellifera* L.) in relation to increased resistance to the Varroa mite (*Varroa jacobsoni* Oud.). **Tidsskrift for Planteavl** 90, 293-299.

Schousboe C (1990). Seasonal variation in duration of capped stage in worker bee brood. **Tidsskrift for Biavl** 124, 50-52.

Shaw KE, Davidson G, Clark SJ, Ball BV, Pell JK, Chandler D & Sunderland KD (2002). Laboratory bioassays to assess the pathogenicity of mitosporic fungi to *Varroa destructor* (Acari: Mesostigmata), an ectoparasitic mite of the honeybee, *Apis mellifera*. **Biological Control** 24, 266-276.

Shimanuki H & Knox DA (2000). **Diagnosis of honey bee diseases**. U.S. Department of Agriculture, Agriculture Handbook No. ah-690, Washington, 61 pp.

Shimanuki H, Knox DA, Furgala B, Caron DM & Williams JL (1992). Diseases and pests of honey bees. *In* **The hive and the honeybee**, Graham J (ed.). Dadant and Sons, Hamilton, Illinois, pp.1083-1151.

Shimanuki H, Calderone N & Knox D (1994). Parasitic mite syndrome: the symptoms. **American Bee Journal** 134, 827-828.

Singh JN & Venkatraman TV (1947). Pseudoscorpions in beehives in India. **Current Science** 16,122.

Smith FG (1960). **Beekeeping in the tropics**. Longmans, Green, London.

Spivak M (1996). Honey bee hygienic behaviour and defense against *Varroa jacobsoni*. **Apidologie** 27, 245-260.

Spivak M & Downey DL (1998). Field assays for hygienic behaviour in honey bees (Apidae: Hymenoptera). **Journal of Economic Entomology** 91, 64-70.

Spivak M & Gilliam M (1998). Hygienic behaviour of honeybees and its application for control of brood diseases and varroa. **Bee World** 79, 169-186.

Spivak M & Reuter GS (1998). Performance of hygienic colonies in a commercial apiary. **Apidologie** 29, 291-302.

Spivak M & Reuter GS (2001). *Varroa destructor* infestation in untreated honey bee (Hymenoptera: Apidae) colonies selected for hygienic behaviour. **Journal of Economic Entomology** 94, 326-331.

Spreafico M, Eördegh FR, Bernardinelli I & Colombo M (2001). First detection of strains of *Varroa destructor* resistant to coumaphos. Results of laboratory and field trials. **Apidologie** 32, 49-55.

Steiner J, Dittman F, Rosenkranz P & Engels W (1994). The first gonocycle of the parasitic mite (*Varroa jacobsoni)* in relation to preimaginal development of its host, the honey bee (*Apis mellifera carnica*). **Invertebrate reproduction and development** 25, 175-183.

Steiner KE (1987). Breeding systems in the Cape flora. *In* **A preliminary synthesis of pollination biology in the Cape flora**, Rebelo AG (ed.), South African National Scientific Programmes Report 141, Pretoria, pp. 22-51.

Subbiah MS, Mahadevan V & Janakiraman R (1957). A note on the occurrence of an arachnid — *Ellingsenius indicus* Chamberlin — infesting bee hives in south India. **Indian Journal of Veterinary Science** 27, 155-156

Sudarsanam D & Murthy VA (1990). Phoretic association of the pseudoscorpion *Ellingsenius indicus* with *Apis cerana indica*. *In* **Social Insects and the Environment**, ed. G.K. Veeresh, B. Mallik & C.A. Viraktamath, Oxford & IBH Publishing Co., New Delhi, pp. 721-722.

Taber S (1982). Bee behaviour: Breeding for disease resistance. **American Bee Journal** 122, 177-179.

Taylor M (2005). Varroa destuctor Not Thwarted by Smaller Cells. **Scottish Beekeeper** 82, 252-253.

Tewarson NC (1987). Use of host haemolymph proteins, seasonal reproduction and a hypothesis on nutritional imprinting in the honey bee mite, *Varroa jacobsoni*, on *Apis mellifera* and *Apis cerana*. *In* **Chemistry and Biology of Social Insects**, Eder J & Rembold H (eds.), J. Peperny, Munich, pp. 688-689.

Tewarson NC, Singh A & Engels W (1992). Reproduction of *Varroa jacobsoni* in colonies of *Apis cerana indica* under natural and experimental conditions. **Apidologie** 23, 161-171.

Thakur RJ, Bienefeld K & Keller R (1997). Varroa defense behaviour in *A.mellifera carnica*. **American Bee Journal** 137, 143-148.

Thomas H-U (1997). Practical aspects of alternative varroa control methods. *In* **Varroa! Fight the mite**, Munn P & Jones R (eds.). International Bee Research Association, Cardiff, pp. 3-10.

Thompson HM, Brown MA, Ball RF 7 Bew MH (2002). First report of *Varroa destructor* resistance to pyrethroids in the UK. **Apidologie**, 33, 357-366.

Thrasyvoulou AT, & Pappas N (1988). Contamination of honey and wax with malathion and coumaphos used against the varroa mite. **Journal of Apicultural Research** 27, 55-61.

Trouiller J (1998). Monitoring *Varroa jacobsoni* resistance to pyrethroids in Western Europe. **Apidologie** 29, 537-546.

Trouiller J, Arnold G, Le Conte Y & Masson C (1991). Temporal pheromonal and kairomonal secretion in the brood of honeybees. **Naturwissenschaften** 78, 368-370.

Vandame R (1996). Importance de l'hybridation de l'hôte dans la tolerance à un parasite. Cas de l'acarien parasite *Varroa jacobsoni* chez les races d'abeilles *Apis mellifera* européenne et africanisée au Mexique. PhD dissertation, Université Claude Bernard Lyon 1, France, pp. 1-111.

Vandame R, Colin ME & Otero-Colina G (1997). Africanized honey bees tolerance to *Varroa* in Mexico: mite infertility is not the main tolerance factor. **XXXVth International Apimondia Congress**, Antwerp, Belgium.

Vandame R, Colin ME & Otero-Colina G (1999). Africanized honey bees tolerance to *Varroa* in Mexico: Mite infertility is not the main tolerance factor. **Apiacta** 34, 12-20.

Vandame R, Colin ME, Morand S & Otero-Colina G (2000). Levels of compatibility in a new host-parasite association: *Apis mellifera*/*Varroa jacobsoni*. **Canadian Journal of Zoology** 78, 2037-2044.

Vandame R, Morand S, Colin ME & Belzunces LP (2002). Parasitism in the social bee *Apis mellifera*: quantifying costs and benefits of behavioural resistance to *Varroa destructor* mites. **Apidologie** 33, 433-445.

Van Buren NWM , Mariën J, Velthuis HHW & Oudemans RCHM (1992). Residues in beeswax and honey of perizin, an acaracide to combat the mite *Varroa jacobsoni* Oudemans (Acari: Mesostigmata). **Environmental Entomology** 21, 860-865.

Van Dung N, Tan NQ, Huan LV & Boot WJ (1997). Control of honey bee mites in Vietnam without the use of chemicals. **Bee World** 78, 78-83.

Van Veen J, Calderón RA, Cubero A & Arce H (1998). *Varroa jacobsoni* Oudemans in Costa Rica: detection, spread and treatment with formic acid. **Bee World** 79, 5-10.

Vedova G, Lodesani M & Milani N (1997). Development of resistance to organophosphates in *Varroa jacobsoni*. **Ape Nostra Amica** 19, 6-10.

Wallner A (1997). Sieben Jahre Züchtung auf Varroaresistenz- Die Bilanz. **Imkerfreund** 52, 4-5.

Wallner K (1993). A method for the determination of varroacide residues in beeswax. **Apidologie** 24, 502-503.

Wallner K (1999). Varroacides and their residues in bee products. **Apidologie** 30, 235-248.

Watkins M (1996). Resistance and its relevance to beekeeping. **Bee World** 77, 15-22.

Weinberg KP & Madel G (1985). The influence of the mite *Varroa jacobsoni* Oud. on the protein concentration and the haemolymph volume of the brood of worker bees and drones of the honey bee *Apis mellifera* L. **Apidologie** 16, 421-436.

Wilde J & Koeniger N (1992). Selektion auf Verkürzung der Zellverdeckelungsdauer (ZVD) der Arbeiterinnenbrut von *Apis mellifera carnica*. **Annales Universitatis Mariae Curie Sklodowska** 47, 133-136.

Wilson WT, Baxter J, Ibarra J & Reiners R (1998). Miticides impregnated in plastic for control of *Varroa jacobsoni*. **American Bee Journal** 138, 300-301.

Woyke J (1987). Population dynamic parameters of *Tropilaelaps clareae* in comparison with those of *Varroa jacobsoni* mite on honeybees. **Journal of Apicultural Research** 26, 196-202.

APPENDIX I:
SPREAD OF THE VARROA MITE

August – October 1997 Survey: Beekeeper colonies only

Beekeeper	Date	Town	Designation	Recent History	Colony	Varroa
PPRI	28/08/97	Cape Point	PPRI(1)	Sedentary for 5 years Apiary A	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
					7	0
					8	0
PPRI	28/08/97	Cape Point	PPRI(2)	Sedentary for 5 years Apiary B	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
					7	0
					8	0
Duncan Bates	22/09/97	Smitswinkelbaai	DB1	Sedentary, trapped hives	1	1
					2	18
					3	1
					4	0
					5	1
					6	2
Dick Foster	22/09/97	Smitswinkelbaai	DF2	Sedentary for previous 18 months	1	1
					2	1
					3	1
					4	1
					5	3
					6	0
Mark Ferrow	22/09/97	Noordhoek	MF1	Sedentary	1	9
					2	6
					3	35
					4	15
					5	27
					6	6
Dick Foster	22/09/97	Noordhoek	DF1	Trap-swarms caught in Fishhoek and moved to Noordhoek in last month	1	0
					2	0
					3	0
Peter Gibb	22/09/97	Hout Bay	PG1	Sedentary	1	3
					2	0
					3	2
					4	0
					5	0
					6	0
Robert Post	22/09/97	Tokai	RP1	Sedentary for 12 months	1	5
					2	7
					3	6
					4	0
					5	0
					6	1
Geoff Tribe	22/09/97	Rosebank	GT1	Sedentary	1	18
					2	0
					3	5
					4	17

Ted Rohland	17/10/97	Parow		Sedentary	1	36
					2	12
					3	4
					4	0
Nigel Hollaway	30/09/97	Tableview	NH1	Two very recent trap-swarms,	1	0
				And five feral swarms	2	7
					3	0
					4	3
					5	141
					6	1
					7	2
Carl Runds	20/10/97	Melkbosstrand	Runds	Sedenatry for three years	1	6
					2	9
					3	6
					4	3
Peter Canowie	30/09/97	Melkbosstrand	PC3	Sedentary for 18 months,	1	7
				Previously from Stellenbosch	2	2
					3	4
					4	0
					5	11
					6	17
Ted Rohland	18/10/97	Durbanville	Rohland	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
Campbell McNair	30/09/97	Durbanville	CN1	Sedentary for previous 12	1	0
				Months	2	0
					3	0
					4	2
					5	0
Rolf Kriebel	09/09/97	Philadelphia	RK1	Migratory colonies;	1	0
				Unknown immediate origin	2	0
					3	4
					4	0
					5	0
DS Thiart	25/09/97	Malmesbury	DST(1)	Sedentary	1	1
					2	4
					3	0
					4	7
					5	0
JC Truter	25/09/97	Malmesbury	JCT(1)	Recently used for almond	1	0
				Pollination; then returned to	2	0
				Malmesbury	3	0
					4	0
					5	0
					6	0
WJ Duckitt	25/09/97	Darling	WJD	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
FH van Reenen	25/09/97	Darling	FHvR	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0

JH van der Westhuizen	06/10/97	Moorreesburg	JHvdW	Sedentary	1 2 3 4 5 6	0 0 0 0 0 0
HJ Visser	06/10/97	Moorreesburg	HJV	Sedentary	1 2 3 4 5 6	0 0 0 0 0 0
Mike McIntyre	01/10/97	Hopefield	MM(1)	Recent trap-swarms	1 2 3 4 5	0 0 0 0 0
Fiona Kotze	01/10/97	Hopefield	FK(1)	Sedentary	1 2 3 4 5 6	0 0 0 0 0 0
Fiona Kotze	01/10/97	Hopefield	FK(2)	Sedentary	1 2 3 4 5 6	0 0 0 0 0 0
PWD de la Querra	01/10/97	Saldanha	PWD	Colonies recently moved From Moorreesburg	1 2 3 4 5 6	0 0 0 0 0 0
J Februarie	01/10/97	Saldanha	JF	Sedentary	1 2 3	0 0 0
A Y Louw	01/10/97	Veldrif	AYL	Unknown	1 2 3 4 5 6	0 0 0 0 0 0
N Melch	01/10/97	Veldrif	NM	Sedentary	1 2	0 0
JJP Kotze	01/10/97	Veldrif	JJPK	Sedentary	1 2 3 4 5	0 0 0 0 0
NJ Loubser	01/10/97	Veldrif	NJL	Sedentary	1 2 3 4 5 6	0 0 0 0 0 0
Nico Langenhoven	26/09/97	Het Kruis	NL(1)	Unknown	1 2 3 4 5	0 0 0 0 0

F van der Westhuizen	13/10/97	Citrusdal	FvdW(4)	Sedentary	1 2 3 4 5 6	0 0 0 0 0 0
J Bredankamp	13/10/97	Citrusdal	JB	Sedentary	1 2 3 4 6 7 8	0 0 0 0 0 0 0
F van der Westhuizen	13/10/97	Citrusdal	FvdW(3)	Two trap-swarms	1 2	0 0
G Marais	13/10/97	Citrusdal	GM(1)	Sedentary	1	0
S Bestbier	13/10/97	Citrusdal	SB(1)	Sedentary	1 2 3 4 5	0 0 0 0 0
K Slabber	13/10/97	Citrusdal	KS	Sedentary	1 2 3	0 0 0
F van der Westhuizen	13/10/97	Citrusdal	FvdW(2)	Sedentary	1	0
F van der Westhuizen	13/10/97	Citrusdal	FvdW(1)	Sedentary	1 2 3	0 0 0
Paul Van Mieghem	06/10/97	Piketberg	PavM(4)	Sedentary	1 2 3 4 5 6	0 0 0 0 0 0
Paul van Mieghem	06/10/97	Piketberg	PavM(5)	Sedentary	1 2 3 4 5	0 0 0 0 0
C Engelbrecht	06/10/97	Piketberg	CE(1)	Sedentary	1 2 3	0 0 0
Paul van Mieghem	06/10/97	Porterville	PavM(3)	Sedentary	1 2 3 4 5 6	0 0 0 0 0 0
Paul van Mieghem	06/10/97	Porterville	PavM(2)	Sedentary	1 2 3 4 5 6	0 0 0 0 0 0
Paul van Mieghem	06/10/97	Porterville	PavM(1)	Sedentary	1 2 3 4 5	0 0 0 0 0

Nico Langenhoven	26/09/97	Porterville		Sedentary; one year old trap swarms	1 2 3 4 5	0 0 0 0 0
Nico Langenhoven	26/09/97	Porterville	NL	Sedentary	1 2 3 4 5	0 0 0 0 4
O Erasmus	08/10/97	Tulbagh	OE(1)	Sedentary	1 2 3 4 5 6	0 0 0 0 0 0
Peter Lawson	08/10/97	Ceres	PL(1)	Local migration	1 2 3 4 5	0 0 0 0 0
DC Lourens	08/10/97	Ceres	DCL(1)	Sedentary	1 2 3	0 0 0
Mr Groenewald	08/10/97	Wolesely	Groenewald 1	Sedentary	1 2 3 4 5	0 0 0 0 0
Davis	08/10/97	Wellington	D(II)	Sedentary	1 2 3 4 5 6	0 0 0 0 0 1
DJ Schneider	08/10/97	Wellington	DJS(1)	Sedentary	1 2 3 4 5 6	6 8 4 0 1 0
Davis	08/10/97	Wellington	D	Sedentary	1 2 3 4 5 6	3 0 0 0 7 0
Danie Walters	22/09/97	Paarl	DM	Sedentary	1 2 3 4 5 6	0 0 1 0 1 0
JJ Carsten	25/09/97	Paarl	JJC(1)	Sedentary	1 2 3 4 5 6	2 23 5 5 1 0

Paul Ransom	27/08/97	Paarl	PR2	Commercial migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	4
PPRI	22/08/97	Elsenburg	PPRI-River	Local migration	1	1
					2	3
					3	2
					4	1
					5	0
					6	1
PPRI	22/08/97	Elsenburg	PPRI-Rond	Local migration	1	2
					2	5
					3	0
					4	1
					5	1
					6	2
Nico Langenhoven	27/08/97	Klapmuts	NicoL	Sedentary	1	0
					2	2
					3	1
					4	1
					5	0
					6	0
					7	0
					8	0
Jaco Lourens	26/08/97	Klapmuts	JL1	Sedentary	1	10
					2	7
					3	6
					4	2
					5	3
					6	0
Robert Post	24/08/97	Koelenhof	POST	Commercial migration	1	1
					2	0
					3	0
					4	2
					5	9
					6	0
Rolf Kriebel	26/08/97	Kraaifontein	RK2	Commercial migration	1	0
					2	1
					3	7
					4	4
					5	0
					6	2
Hennie Mostert	05/09/97	Stellenbosch	HM1	Sedentary	1	12
					2	3
					3	0
					4	3
					5	0
					6	0
					7	0
					8	0
Peter Canowie	02/09/97	Stellenbosch	PC1	Commercial migration	1	5
					2	22
					3	6
					4	30
Karen Chalenor	11/10/97	Stellenbosch	Karen	Sedentary	1	72
					2	11
					3	17
Rolf Kriebel	28/08/97	Vlottenberg	RK3	Commercial migration	1	1
					2	9
					3	2

D Uys	27/09/97	Somerset West	DU1	Sedentary	1 2 3 4 5 6	2 0 4 6 3 1
Paul Rnsom	27/08/97	Somerset Wset	PR1	Commercial migration	1 2 3 4 5 6	2 1 1 2 0 1
J Visagie C Steyl	29/09/97	Strand	JV1	Sedentary	1 2 3 4 5	0 0 1 0 0
Robert Post	27/09/97	Gordons Bay	RP	Commercial migration; Sedentary for 12 months	1 2 3 4 5 6 7 8	1 0 1 2 1 3 1 0
Hennie Muller	01/10/97	Grabouw	HM1	Commercial migration	1 2 3 4 5 6	0 1 0 0 0 0
Hans Kiessling	01/10/97	Pringle Bay	HK1	Commercial migration	1 2 3 4 5 6	0 0 0 0 0 0
Hans Kiessling	01/10/97	Betty's Bay	HK2	Commercial migration	1 2 3 4 5	0 0 4 0 3
Hans Kiessling	01/10/97	Kleinmond	HK3	Commercial migration	1 2 3 4 5 6	0 0 0 0 0 0
Hans Kiessling	01/10/97	Kleinmond	HK4	Commercial migration	1 2 3 4 5 6	0 0 0 0 0 0
Mr Fouchee	01/10/97	Kleinmond	F1	Sedentary	1 2 3 4	0 0 0 0
Mr Steyn	01/10/97	Hermanus	S1	Sedentary	1 2 3 4 5 6	0 0 0 0 0 0

Mrs Siebman	01/10/97	Hermanus	SM1	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
Hans Kiessling	01/10/97	Stanford	HK5	Commercial migration	1	0
					2	0
					3	0
					4	0
					5	0
Hennie Muller	01/10/97	Stanford	HM2	Commercial migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Peter Canowie	06/10/97	Gansbaai		Commercial migration	1	0
					2	0
					3	0
					4	0
Nico Esterhuyse	23/10/97	Elim	Elim	Commercial migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
					7	0
					8	0
Hennie Muller	01/10/97	Bredasdorp	HM3	Commercial migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Johan van Eck	28/08/97	Bredasdorp		Commercial migration	1	0
					2	0
					3	0
					4	0
John Moodie	12/10/97	Bredasdorp	Moodie	Commercial migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Mr Casselman	05/10/97	Swellendam	Malgas	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
					7	0
Nico Langenhoven	01/09/97	Swellendam	NL1	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
					7	1
					8	0
Jan Hanekom	23/10/97	Riviersonderend	Hanekom	Sedentary	1	0
					2	0
					3	0

Jan Hanekom	23/10/97	Riviersonderend	Hanekom	Sedentary	1	0
					2	0
					3	0
Jan Hanekom	23/10/97	Riviersonderend	Hanekom	Sedentary	1	0
					2	0
					3	0
Hans Kiessling	01/10/97	Caledon	HK6	Commercial migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
J Kellerman	23/10/97	Caledon	Kellerman	Commercial migration	1	0
					2	0
					3	1
					4	2
					5	1
					6	0
JP le Roux	22/09/97	Villiersdorp	JPLR(1)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Videl Hall	22/09/97	Villiersdorp	VH(1&2)	Sedentary	1	0
					2	0
					3	0
					4	1
					5	0
					6	78
Mrs Rabie	22/09/97	Franschhoek	R(1)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Mrs Rabie	22/09/97	Franschhoek	R(2)	Sedentary	1	0
					2	3
					3	0
					4	0
					5	4
					6	0
Paul Ransom	27/08/97	Franschhoek	PR3	Commercial migration	1	0
					2	0
					3	0
					4	0
					5	1
					6	0
					7	0
					8	0
Paul Ransom	27/08/97	Franschhoek	PR3	Commercial migration	1	0
					2	0
					3	0
					4	2
					5	1
					6	1
					7	15
					8	0
LT Vice	20/10/97	Worcester	LTV(1)	Local migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0

F Du Toit	20/10/97	Worcester	FduT(1)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
Dawid Smit	20/10/97	Robertson	DS(1)	Local migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Dawid Smit	20/10/97	Robertson	DS(2)	Local migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
J Burger	20/10/97	Montagu	JB(1)	Local migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
N van der Merwe	20/10/97	Montagu	NvdM(1)	Local migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
J Fourie	21/10/97	Touwsrivier	JF(1)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
T Basson	15/10/97	Clanwilliam	TB(1)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
HDM Gastyn	15/10/97	Graafwater	HDMG(1)	Sedentary	1	0
					2	0
					3	0
					4	0
HC Louw	15/10/97	Lamberts Bay	HCL(1)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
F van der Westhuizen	13/10/97	Koekenaap	FvdW(7)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
F van der Westhuizen	13/10/97	Lutzville	FvdW(6)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0

F van der Westhuizen	13/10/97	Vredendal	FvdW(5)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
A Wiese	13/10/97	Van Rhynsdorp	AW(1)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
WP O'Kennedy	14/10/97	Niewoudtsville	WPO(1)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
WP Spangenberg	14/10/97	Calvinia	WPS(1)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
JP Venter	14/10/97	Calvinia	JPV(1)	Sedentary	1	0
					2	0
					3	0
					4	0
IJ van Heerden	21/10/97	Beaufort West	IjvH(1)	Sedentary	1	0
					2	0
					3	0
					4	0
CJ Steenkamp	21/10/97	Beaufort West	CJS(1)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
Jo Spanner	20/10/97	Laingsburg	JOS(1)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
W Bourbon-Lefty	20/10/97	Laingsburg	WBL(1)	Sedentary	1	0
					2	0
					3	0
MJ Holtshauzen	20/10/97	Ladismith	MJH(2)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
MJ Holtshauzen	20/10/97	Ladismith	MJH(1)	Sedentary	1	6
					2	2
					3	0
					4	0
					5	0
JBM Thiart	21/10/97	Matjiesfontein	JBMT(1)	Sedentary	1	0
					2	0
JBM Thiart	21/10/97	Matjiesfontein	JBMT(2)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0

Rossouw Swart	07/10/97	Barrydale	Rossouw	Sedentary	1	3
					2	0
					3	10
					4	1
					5	0
John Moodie	13/10/97	Heidelberg	Heidel	Commercial migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Pillie Keyser	13/10/97	Heidelberg	Keyser	Sedentary	1	0
					2	0
					3	0
					4	0
John Moodie	13/10/97	Witsand		Commercial migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
					7	0
					8	0
Denys Visser	07/10/97	Vermaaklikheid	Vermaak	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
					7	1
					8	0
Steven Nease	11/10/97	Stilbaai	Stilbaai	Sedentary	1	0
					2	0
					3	0
John Moodie	12/10/97	Gouritsriviermond	Gourits	Commercial migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Clay Whittal	08/10/97	George	Whittal	Commercial migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Ronnie Strydom	08/10/97	Oudsthoorn	Ronnie2	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Ronnie Strydom	08/10/97	Oudtshoorn	Ronnie1	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Johan Lategan	08/10/97	Oudtshoorn	Lategan	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0

Eben Brand	11/10/97	Plettenberg Bay	Plett	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Menno Alting	09/10/97	Port Elizabeth	Menno2	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Menno Alting	09/10/97	Port Elizabeth	Menno1	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Mike Taylor	09/10/97	Port Elizabeth	Taylor	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
Bill Pearce	09/10/97	Somerset East	Pearce	Commercial migration	1	0
					2	0
					3	0
Graham Cambrey	10/10/97	Grahamstown	Graham2	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Graham Cambrey	10/10/97	Grahamstown	Graham1	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Charles Frederichs	11/10/97	Port Alfred	Alfred	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Kola le Roux	11/10/97	East London	Kola	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Charles Frederichs	10/10/97	Fort Beaufort	Fort Beau	Local migration	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Hendrik Pasengrow	10/10/97	Queenstown	Queens	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0

Kolenie Stegmann	11/10/97	Mortimer	Steg	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Jan van Heerden	11/10/97	Mortimer	JanV	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Dr Marais	11/10/97	Graaff Reinet	Graaff	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
Richard Booth	18/09/97	Harding	SKN-Q1	Sedentary	1	0
					2	0
					3	0
					4	0
Richard Booth	18/09/97	Harding	SKN-Q2	Sedentary	1	0
					2	0
					3	0
					4	0
Ron Botha	17/09/97	Highflats	SKN-R	Local migration	1	0
					2	0
					3	0
					4	0
Pat Nolan	16/09/97	Richmond	SKN-T1	Sedentary	1	0
					2	0
					3	0
					4	0
Pat Nolan	16/09/97	Richmond	SKN-T2	Sedentary	1	0
					2	0
					3	0
					4	0
Reg Morgan	15/09/97	Greytown	SKN-P	Sedentary	1	0
					2	0
					3	0
					4	0
Johan Snyders	30/09/97	Vryheid	NKN-V1	Commercial migration	1	0
					2	0
					3	0
					4	0
Johan Snyders	30/09/97	Vryheid	NKN-V2	Commercial migration	1	0
					2	0
					3	0
					4	0
Walter Mein	01/10/97	Piet Retief	MP-N1	Sedentary	1	0
					2	0
					3	0
					4	0
Walter Mein	01/10/97	Piet Retief	MP-N2	Sedentary	1	0
					2	0
					3	0
					4	0

Robin Mountain	02/10/97	Piet Retief	MP-O1	Local migration	1	0
					2	0
					3	0
					4	0
Robin Mountain	02/10/97	Piet Retief	MP-O1	Local migration	1	0
					2	0
					3	0
					4	0
Buks Nel	23/10/97	Nelspruit	MP-B1	Commercial migration	1	0
					2	0
					3	0
					4	0
Buks Nel	23/10/97	Nelspruit	MP-B2	Commercial migration	1	0
					2	0
					3	0
					4	0
Gerald Beverly	23/10/97	Malelene	MP-G1	Commercial migration	1	0
					2	0
					3	0
					4	0
Gerald Beverly	23/10/97	Malelene	MP-G2	Commercial migration	1	0
					2	0
					3	0
					4	0
Michael Lutz	24/10/97	White River	MP-M1	Commercial migration	1	0
					2	0
					3	0
					4	0
Michael Lutz	24/10/97	White River	MP-M2	Commercial migration	1	0
					2	0
					3	0
					4	0
Louis Jordaan	07/10/97	Tzaneen	NP-X1	Commercial migration	1	0
					2	0
					3	0
					4	0
Chris James	08/10/97	Louis Trichardt	NP-Y1	Commercial migration	1	0
					2	0
					3	0
					4	0
Chris James	08/10/97	Louis Trichardt	NP-Y2	Commercial migration	1	0
					2	0
					3	0
					4	0
Hans Groenewald	10/10/97	Nylstroom	NG-AA	Commercial migration	1	0
					2	0
					3	0
					4	0
Neil McClellan	06/10/97	Warmbaths	NG-W1	Commercial migration	1	0
					2	0
					3	0
					4	0
James Williams	23/09/97	Pretoria	NG-U	Commercial migration	1	0
					2	0
					3	0
					4	0
PPRI	25/08/97	Pretoria	PPRI(5)	Sedentary	1	0
					2	0
					3	0
					4	0
					5	0

Renier Strydom	27/08/97	Evander	SG-L1	Sedentary	1	0
					2	0
					3	0
					4	0
Renier Strydom	27/08/97	Evander	SG-L2	Sedentary	1	0
					2	0
					3	0
					4	0
Chris Botha	16/08/97	Derby	SG-K	Sedentary	1	0
					2	0
					3	0
					4	0

1998 surveys & *ad hoc* samples: Beekeeper colonies only

R Kriebel	15/02/98	Joostenburg	Philadelphia/ Alexandra		1	11
					2	23
					3	7
					4	4
					5	1
					6	79
= K1					7	0
					8	2
					9	36
					10	49
					11	27
					12	50
					13	7
					14	5
					15	1
					16	19
					17	31
					18	45
					19	16
					20	12
					21	14
					22	9
					23	6
					24	25
					25	7
					26	0
					27	107
					28	39
					29	2
					30	17
					31	21
PPRI	16/02/98	Elsenburg	PPRI (1)		1	0
					2	4
					3	9
					4	7
= P1					5	3
					6	27
					7	6
					8	0
					9	8
					10	6
			PPRI (2)		1	0
					2	0
					3	0
= P1					4	8
					5	0
					6	9
					7	4
					8	0
					9	0
					10	6

Nico Langenhoven	27/02/98	Paarl			1	2
					2	7
					3	0
					4	0
					5	8
					6	5
= L1					7	0
					8	1
					9	1
					10	3
					11	5
					12	12
					13	0
					14	2
					15	0
					16	1
					17	0
					18	0
					19	5
					20	10
					21	3
					22	2
					23	2
					24	5
Hunter	09/02/98	Durbanville	Klipheuwel	Honey room	1	12
					KVII	2
			Malmesbury		KVI	1
Mostert	08/04/98	Stellenbosch			1	1
		(Welgevallen)			2	2
					3	8
					4	3
					5	2
					6	5
					7	7
					8	4
					9	7
					10	1
					11	0
	09/04/98	Vredenburg		Sedentary	1	7
		Plaasrivier			2	4
	09/04/98	Vredenburg			1	4
	20/04/98	Schoonzigcht			1	4
	24/04/98	Protea Heights			1	1
	29/04/98	De Boord			1	0
Blake	27/05/98	Stellenbosch		Sedentary	B1	38
		(Libertasplaas)			B2	12
					B3	24
					B4	3
Mostert	27/05/98	Stellenbosch	Welgevallen	Sedentary	WI 1	6
					WI 2	16
					WI 3	1
					WII 1	6
					WII 2	1
					WII 3	4
N. Esterhuyse	04/06/98	Elim District	Viljoenshof	Rietfontein – vangkas	1	0
				Kleinberg – Viljoenshof	1	0
				Kleinberg – Viljoenshof	2	0
				Kleinberg – Viljoenshof	3	0
				Kaia	1	0
				Kaia	2	0
				Kaia	3	2
				Kaia	4	0
				Laserena I	1	0
				Laserena II	1	1
				Laserena II	2	1
				Laserena III	1	0
				Laserena III	2	0
				Laserena III	3	0

F van der Westhuizen	11/08/98	Citrusdal		Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
					7	0
					8	0
					9	0
					10	0
Blake	14/09/98	Stellenbosch (Libertas Farms)	Dam Sloot		1	62
					2	4
Hendrick O'rien	06/10/98	Eerste rivier		Swerm van Athlone	1	20
Du Toit	06/10/98	Somerset West		Maand na intrek	1	0
					2	3
					3	7
					4	6
Hennie Muller	10/98	Molteno farm		Sedentary	1	0
					2	1
					3	0
					4	2
R. Kriebel	4/11/98	Joostenburg	Philadelphia/ Alexandra		1	117
					2	16
					3	128
					4	69
					5	114
					6	88
					7	62
= K2					8	5
					9	97
					10	56
					11	103
					12	38
					13	103
					14	140
					15	146
					16	105
					17	21
					18	35
					19	47
					20	114
					21	225
					22	64
					23	62
					24	45
					25	74
					26	61
					27	58
					28	52
					29	131
					30	54
					31	85
					32	83
					33	59
					34	148
					35	325
					36	238
					37	115
		Klapmuts Hospital		Sedentary	38	22
					44	106
					42	91
					40	6
					39	8
					43	42
					41	45
					45	3

Jannie Fourie	11/11/98	Touwsriver		Huistrekswerm van Barrydale	1	1
					2	0
Jaap Coetzee	11/11/98	Touwsriver		Sedentary	1	0
				Bye gekoop op Ceres	2	2
					3	0
					4	1
					5	0
Van Aarde	11/11/98	Touwsriver	By Huis	Sedentary	1	0
					2	0
Thys Niehaas		Touwsriver		Bestuiwing in Ceres	1	1
				Sedentary	2	2
					3	1
					4	0
					5	0
					6	0
Koos Spaner		Laingsburg		Uie bestuiwing Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
					7	0
					8	0
Thiart		Matiesfontein		Sedentary	1	0
				Bye op Laingsburg	2	0
					3	0
					4	0
					5	0
					6	0
					7	0
					8	0
Hans Kiessling	12/11/98	Vleiland	Zandrivier	Bestuiwing op uie	1	0
					2	0
					3	0
Andries Smit	12/11/98	Vleiland	Zandrivier	Sedentary	1	0
				Uiebestuiwing	2	0
					3	0
					4	0
Andries Smit	12/11/98	Vleiland	Doringkloof	Plaaslik Doringkloof	1	0
				Uiebestuiwing	2	0
					3	0
					4	0
					5	0
N v d Merwe	12/11/98		Doringkloof	Bye van Montagu	1	0
					2	0
					3	0
					4	0
Jaco Zwiegelaar	12/11/98	Prince Albert		Uiebestuiwing en wortels	1	0
					2	0
					3	0
					4	0
S Kellerman	12/11/98	Prince Albert		Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
Chris Steenkamp	13/11/98	Beaufort Wes		Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
					7	0

Danie Fourie	13/10/98	Leeu Gamka		Bye op George gekoop	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
				Bye plaaslik	7	0
					8	0
					9	0
					10	0
					11	0
K van Niekerk	22/10/98	Kenhardt		Gevang op plaas	Boorgat	0
					Erdvarkgat	0
				Kokerboomwoud	Klipkop	0
W A Burger	23/10/98			Sedentary	Huis	0
					Hek	0
					Veld I	0
					Veld II	0
A van der Westhuizen	22/10/98	Kenhardt		Wilde bye	Boorgat	0
					Erdvarkgat	0
E. Svenson	23/10/98	Keimoes	Rivier	Patente korwe (swak)	1	0
					2	0
					3	0
					4	0
					5	0
					6	0
			Klipkop		1	0
					2	0
					3	0
					4	0
					5	0
Koos Brink	23/10/98	Keimoes	Teen koppie	Patente Korwe (redelik)	1	0
					2	0
					3	0
					4	0
			Plaas		1	0
					2	0
					3	0
J Agenbagh	24/10/98	Kakamas	By huis		1	0
					2	0
					3	0
			Langs kraal		1	0
					2	0
					3	0
					4	0
					5	0
					6	0
B Grobler	24/10/98	Keimoes	Houthoop	Wilde swerms	1	0
			Pomphuis		2	0
			Patente korwe		1	0
			Patente korwe		2	0
N Esterhuyse	11/11/98	Joostenberg vlakte		Sedentary	1	3
					2	3
					3	1
					4	6
					5	26
					6	1
					7	5
					8	3
					9	9
					10	14

J P le Roux		Villiersdorp	Berg I	Sedentary	1	1
				Uiebestuiwing	2	8
					3	8
			Berg II		1	0
					2	0
					3	1
					4	1
Rabie		Franschoek	Berg	Uiebestuiwing	1	30
					2	48
					3	53
					4	43
			Huis		1	29
					2	26
D Malan	18/11/98	Hugenot- Paarl		Bye op waboom	1	32
				Uiebestuiwing	2	9
					3	11
					4	5
					5	31
J J Carsten	18/11/98	Paarl		Uiebestuiwing	1	15
					2	14
					3	44
					4	41
					5	24
					6	3
D S Thiart	18/11/98	Malmesbury		Uiebestuiwing	1	6
					2	3
J C Truter	18/11/98	Malmesbury		Uiebestuiwing	1	5
					2	8
					3	6
					4	19
F van der Merwe	23/11/98	George		Bye op Hoekwil	1A	0
					2A	0
					3A	0
					4A	0
					1B	0
					2B	0
					3B	0
					4B	0
				George huis	1	0
					2	0
					3	0
Hennie Steyl	23/11/98	George		Bye anderkant Knysna	1A	0
					2A	0
					3A	0
					4A	0
					5B	0
					6B	0
					7B	0
					8B	0
					9B	0
					10B	0
					11B	0
Chris Mostert	23/11/98	Plettenbergbaai		Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
Des Akers		Port Elizabeth		Sedentary	1	0
					2	0
					3	0
					4	0
					5	0
					6	0

Bill Pearce	23/11/98	Port Elizabeth	Sedentary	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
Menno Alting	23/11/98	Port Elizabeth	Sedentary	1A	0
				2A	0
				3A	0
				4A	0
				5A	0
				6A	0
Menno Alting	23/11/98	Port Elizabeth	Sedentary	1B	0
				2B	0
				3B	0
				4B	0
				5B	0
				6B	0
Kola le Roux	23/11/98	East London		1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
				9	0
				10	0
Charles Frederichs	23/11/98	Port Alfred		1A	0
				2A	0
				3A	0
				4A	0
				5A	0
				6A	0
				1B	0
				2B	0
				3B	0
				4B	0
				5B	0
				6B	0
Leo Herselman	23/11/98	Port Alfred	Bye op Bathurst	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
	23/11/98	Port Alfred	Bye in Dorp	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
Hendrick Botes	23/11/98	Jeffreysbaai	Bye op van Stadens pos	1A	0
				2A	0
				3A	0
				4A	0
				5A	0
				6A	0
				1B	0
				2B	0
				3B	0
				4B	0
				5B	0
				6B	0

Ronnie Strydom	23/11/98	Oudtshoorn	Bye op proef plaas	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
Ronnie Strydom	23/11/98	Oudtshoorn	Bye op Grotte Uiebestuiwing	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
Lofty Eaton	23/11/98	Oudtshoorn	Bye op Oudtshoorn Bestuiwing appels & wortels	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
Mark Myburgh	11/98	Richmond (4) EL site	2-3 year old colonies	1	58
				2	43
				3	79
				4	55
				5	95
				6	79
				7	49
				8	95
				9	49
				10	44
				11	28
				12	66
				13	39
				14	88
				15	114
				16	174
				17	80
				18	82
				19	76
Mark Myburgh	11/98	Richmond (5) KD/W site	2-3 year old colonies	1	98
				2	126
				3	12
				4	133
				5	70
				6	70
				7	73
				8	32
				9	68
				10	101
				11	42
				12	87
				13	62
				14	90
				15	52
				16	108
				17	68
				18	61
				19	113
Pierre Jevon	12/98	Umdloti Beach	Sedentary	1	1
				2	2
				3	1
				4	2
Ken Armstrong	12/98	Amanzimtoti	Sedentary	1	1
Ron Botha	12/98	Highflats (1)	Trapped mid 1998	1	9
				2	1
				3	1
				4	1

Ron Botha	12/98	Highflats (2)	Trapped mid 98	1	0
				2	1
				3	1
				4	2
				5	2
				6	0
Keith Langton Brian Hansen Dave Pearce	12/98	Uvango (1)	Moved from Harding	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
		Margate	Moved from Harding	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
				9	1
				10	0
				11	0
				12	1
				13	0
				14	0
				15	0
Richard Booth	12/98	Harding (1) Willey site	Trapped 1998	1	0
				2	0
				3	0
				4	0
		Harding (2) Ronnies	Trapped in 1998	1	0
				2	0
				3	0
				4	0
				5	0
		Harding (3) Home	Trapped in 1998	1	2
				2	1
				3	1
				4	1
				5	1
				6	0
				7	0
				8	0
				9	0
				10	0
				11	0
		Harding (4) Deemont	Trapped in 1998	1	0
				2	0
				3	0
				4	0
Barrie Lewis	12/98	Hilton (1)	2-3 year old colonies	1	38
				2	14
				3	9
				4	35
				5	11
				6	12
		Hilton (2)	1-2 year old swarms	1	26
				2	18
				3	14
				4	32
				5	17
				6	29
		Hilton (3)	1-2 year old colonies	1	20
				2	8
				3	45

Mark Bestell	12/98	Pietremaritzburg		1	33
				2	14
Justin Thacker	12/98	Baynesfield (1) Atherstone	Permanent 3 year old colony	1	39
		Baynesfield (2) Pumphouse	New swarm 2 months old	1	17
		Baynesfield (3) Rhodiadale	Permanent 3 year old colony	1	15
Mr Clarkson	12/98	Shongweni	Permanent	1	1
				2	9
				3	9
				4	5
				5	9
Melvyn Dawson	12/98	Westville (1)	Permanent	1	45
				2	1
		Westville (2)	New swarm	1	0
		Westville (3)	New swarm	1	2
				2	0
		Durban North	New swarm	1	0
Rod Lodwig	12/98	Pinetown	Permanent	1	3
George May	12/98	Kloof	Permanent	1	0
				2	22
				3	3
				4	8
Barrie Barnard	12/98	Richard Bay	1 year traps from Babanango	1	1
				2	1
				3	3
				4	5
				5	5
				6	1
				7	10
				8	0
				9	3
				10	3
				11	5
				12	5
				13	1
				14	1
				15	1
				16	2
				17	5
				18	2
				19	4
P Nolan	18/9/98	Eston	Capensis Survey	T1	Yes
				T2	Yes
Curtis Fulton	16/10/98	Richmond	Capensis Survey	AH	Yes
Roland Kennard	3/12/98	Pietermaritzburg	Capensis Survey	AO2	Yes
E du Toit	16/2/98	Vredefort	Capensis Survey	A1	0
				A2	0
H van den Heever	9/3/98	Kroonstad	Capensis Survey	B	0
H van den Heever	5/7/98	Kroonstad	Capensis Survey	B	0
E Bowes	9/4/98	Glen	Capensis Survey	C	0
E Bowes	5/6/98	Glen	Capensis Survey	C	0

W Dinkelmann	12/5/98	Parys	Capensis Survey	D	0
W Dinkelmann	4/12/98	Parys	Capensis Survey	D	0
Theuns Engelbrecht	11/2/98	Douglas	Capensis Survey	E	0
Theuns Engelbrecht	19/9/98	Douglas	Capensis Survey	E	0
N Aggenbach	10/2/98	Kakamas	Capensis Survey	G	0
N Aggenbach	18/8/98	Kakamas	Capensis Survey	G	0
S Jordaan	12/2/98	Warrenton	Capensis Survey	H	0
S Jordaan	20/8/98	Warrenton	Capensis Survey	H	0
D van den Berg	10/3/98	Vanderbijlpark	Capensis Survey	J1	0
				J2	0
D van den Berg	25/8/98	Vanderbijlpark	Capensis Survey	J1	0
Chris Botha	26/2/98	Derby	Capensis Survey	K	0
R Strydom	24/2/98	Evander	Capensis Survey	L1	0
				L2	0
R Strydom	28/8/98	Evander	Capensis Survey	L1	0
				L2	0
M Peveret	3/4/98	Kroonstad	Capensis Survey	M	0
W Mein	12/3/98	Piet Retief	Capensis Survey	N2	0
Robin Mountain	12/3/98	Piet Retief	Capensis Survey	O1	0
				O2	0
Reg Morgan	2/3/98	Greytown	Capensis Survey	P	0
Reg Morgan	15/9/98	Greytown	Capensis Survey	P	0
James Williams	24/2/98	Cullinan	Capensis Survey	U	0
James Williams	10/8/98	Cullinan	Capensis Survey	U	0
J Schneiders	16/4/98	Ermelo	Capensis Survey	V1	0
				V2	0
J Schneiders	10/11/98	Ermelo	Capensis Survey	V1	0
				V2	0
L Jordaan	24/4/98	Tzaneen	Capensis Survey	X1	0
				X2	0
L Jordaan	17/11/98	Tzaneen	Capensis Survey	X1	0
C James	22/4/98	Louis Trichardt	Capensis Survey	Y1	0
				Y2	0
C James	20/10/98	Louis Trichardt	Capensis Survey	Y1	0
				Y2	0
C Gerber	21/4/98	Louis Trichardt	Capensis Survey	Z	0
C Gerber	19/10/98	Louis Trichardt	Capensis Survey	Z	0

H Groenevald	22/7/98	Nylstroom	Capensis Survey	AA	0
H Groenevald	19/11/98	Nylstroom	Capensis Survey	AA	0
Buks Nel	4/1/98	Nelspruit	Capensis Survey	AB	0
Michael Lutz	2/4/98	White River	Capensis Survey	AC1	0
				AC2	0
Michael Lutz	3/11/98	White River	Capensis Survey	AC1	0
				AC2	0
S Little	1/4/98	Graskop	Capensis Survey	AD1	0
				AD2	0
Fred Bence	2/4/98	White River	Capensis Survey	AE	0
H Urquhard	26/3/98	Vryheid	Capensis Survey	AF1	0
				AF2	0
H Urquhard	10/12/98	Vryheid	Capensis Survey	AF1	0
				AF2	0
Roger Culbert	15/5/98	Skeerpoort	Capensis Survey	AG	0
Roger Culbert	29/10/98	Skeerpoort	Capensis Survey	AG	0
C Le Roux	20/5/98	Westonaria	Capensis Survey	AH1	0
				AH2	0
C Le Roux	24/11/98	Westonaria	Capensis Survey	AH1	0
				AH2	0
K van der Merwe	11/6/98	Pretoria	Capensis Survey	AI	0
K van der Merwe	6/11/98	Pretoria	Capensis Survey	AI	0
Arthur Hunt	24/4/98	Tzaneen	Capensis Survey	AJ	0
Anton Schehle	18/5/98	Pretoria	Capensis Survey	AK1	0
				AK2	0

1999 surveys & *ad hoc* samples: Beekeeper colonies only

Stephan Hartung	05/03/99	Bloekomspruit (OFS)	1	0
			2	0
			3	0
			4	0
			5	0
			6	0
			7	1
Stephan Hartung	05/03/99	Heidelburg (Tvl)	1	0
			2	0
			3	0
			4	0
			5	0
			6	0
			7	0
			8	0
			9	0
			10	0

Stephan Hartung	05/03/99	Heidelburg (Tvl)		11	0
				12	0
				13	0
				14	0
				15	0
				16	0
Stephan Hartung	07/01/99	Heidelburg	Bees from Richmond	1	23
				2	38
				3	7
Robert Post	04/02/99		Bye van Wolseley	1	6
				2	9
				3	15
				4	4
			Bye van Warme Bokkeveld	5	0
Nico Langenhoven	25/01/99	Paarl		1	17
				2	6
				3	12
				4	13
				5	4
				6	5
				7	25
= L2				8	1
				9	16
				10	8
				11	9
				12	7
				13	3
				14	4
				15	1
				16	23
				17	29
				18	3
				19	2
				20	5
				21	7
				22	10
Nico Langenhoven	25/01/99	Porterville		1	13
				2	30
				3	8
				4	3
				5	15
				6	5
				7	14
				8	59
				9	14
				10	2
		Worcester / Karroo		11	8
				12	15
				13	43
				14	16
				15	36
				16	10
				17	11
				18	18
				19	31
				20	13
		Breerivier		21	11
				22	4
				23	4
				24	1
				25	9
				26	13
				27	4
				28	24
				29	3
				30	3

		Slanghoek			31	18
					32	24
					33	6
					34	7
					35	4
					36	4
					37	0
					38	0
					39	14
					40	45
		Malmesbury / Riebeeck Kasteel			41	25
					42	2
					43	11
					44	29
					45	9
					46	2
					47	5
					48	19
					49	5
					50	15
		Malmesbury / Darling			51	2
					52	2
					53	1
					54	6
					55	4
					56	4
					57	7
					58	15
					59	34
					60	1
PPRI	02/02/99	Elsenburg	PPRI(1)	Sedentary	1	2
					2	14
					3	14
					4	23
					5	13
= P2					6	24
					7	27
					8	3
					9	19
					10	20
PPRI	02/02/99	Elsenburg	PPRI(2)	Sedentary	1	1
					2	2
					3	3
					4	11
					5	6
= P2					6	15
					7	25
					8	2
					9	5
					10	22
Fiona Kotze	23/02/99			Bye van Nuweland	1	46
				Bye van Portugeesfontein	2	29
PPRI	24/02/99	Elsenburg		Rivier I	41	0
					65	0
					99	2
					73	6
					36	2
					28	14
					105	1
					97	0
					72	16
					43	16
					30	0
					7	26
					101	8

PPRI	24/02/99	Elsenburg	Rondawel	109	1
				106	9
				4	3
				108	6
				79	13
				31	2
				110	3
			Rivier II	62	9
				48	4
				52	0
				102	7
				45	3
				25	3
				185	0
				24	6
				60	5
				68	5
Jan de La guerra	02/03/99	Hopefield	15km vanaf Kaapstad	1	22
				2	20
				3	7
				4	32
				5	18
				6	10
			Sedentary	7	30
				8	21
				9	9
Fiona Kotze	02/03/99	Hopefield	Sedentary	10	0
				11	30
				12	2
				13	1
				14	0
				15	15
				16	0
				17	4
				18	3
				19	0
				20	5
Theron	02/03/99	Veldrift		1	28
				2	9
				3	12
				4	11
				5	23
				6	11
				7	25
				8	30
				9	48
				10	21
J A Jenkins	02/03/99	Saldanha	Sedentary	1	12
				2	18
				3	9
				4	19
				5	15
				6	2
				7	7
				8	8
				9	36
				10	11
J E Volschenk		Stilbaai		1	0
				2	0
				3	0
				4	0
				5	0

Hennie Visser	09/03/99	Mooreesburg		1	4
				2	0
				3	0
				4	0
				5	0
				6	0
				7	13
				8	0
				9	37
Van Miegheim	09/03/99	Porterville	Piketberg	1	6
				2	1
				3	3
				4	0
				5	0
				6	0
				7	0
			Grootkamp	1	3
			Bestuiwing – Piketberg / Wolseley	2	2
				3	13
				4	0
				5	15
				6	8
				7	4
Van der Merwe			Dasklip	1	5
				2	1
				3	15
				4	28
				5	12
			Bye op Groot Elsbos	1	14
				2	6
				3	6
				4	10
				5	14
				6	9
			Bye op Eendekuil Burger se plaas	1	0
				2	1
				3	1
				4	0
				5	0
				6	0
F van der Westhuizen (Hardy van der Merwe)	09/03/99	Citrusdal	Bye op Karringmelksvlei	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
Charles van der Ross			Karringmelksvlei	1	0
				2	0
				3	0
				4	0
F van der Westhuizen	09/03/99	Citrusdal	Koue Bokkeveld	1	0
				2	0
				3	0
				4	0
				5	0
				6	1
				7	0
				8	0
				9	0
				10	0
				11	0
				12	0
				13	0
				14	0
				15	0

F van der Westhuizen	09/03/99	Citrusdal	Swartvlei	1	0
			Trekswerms	2	0
				3	4
				4	2
Andries Olivier	09/03/99	Clanwilliam	Bye op Tweerivier	1	0
			Die vlei	1	1
			(Dirkie Mouton)	2	1
				3	0
				4	2
				5	4
Leon van der Merwe	10/03/99	Vredendal	Op van Zyl se plaas	1	0
			Bestuiwing	2	0
				3	0
				4	0
				5	0
			Sishen Brug	1	0
			Bye van Tvl in 1998	2	0
				3	0
				4	0
			Trekswerms by huis	1	0
				2	0
				3	0
Boepie O'Kennedy	10/03/99	Niewoudville	Bye by Arendskraal	1	0
			(Toringkamp)	2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
				9	0
				10	0
				1	0
				2	0
				3	0
				4	0
Spangenberg	10/03/99	Calvinia	Bye op plaas (Witwal)	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
				9	0
				10	0
Mike Kotze	11/03/99	Atlantis		1	0
				2	0
				3	1
				4	0
				5	0
				6	2
				7	0
				8	0
				9	2
				10	0
Valgraaf	11/03/99	Van Rynsdorp	Op plaas True-true	1	0
				2	0
				3	0
				4	0
				5	0
				6	0

Page	11/03/99	Koekenaap		1	0
				2	0
				3	0
				4	0
				5	0
Johan Fourie	11/03/99	Koekenaap		1	0
				2	0
				3	0
				4	0
				5	0
				6	0
Vidal Hall	11/03/99	Villiersdorp	Ysterfontein – Clanwilliam	1	8
				2	2
				3	2
				4	5
				5	0
				6	8
Louw	11/03/99	Lambertbaai	Kaapstad	1	0
				2	2
				3	0
				4	0
				5	0
				6	1
Burger	03/99	Montagu	Buite dorp, lucern (n van der Merwe)	1A	0
				2A	1
				3A	0
				4A	0
				5A	0
				6A	3
				7A	0
				8A	0
			Buite dorp, appelkose	1B	0
				2B	1
				3B	0
				4B	0
				5B	1
				6B	0
				7B	2
Charlotte Byeny	03/99	Montagu	Bye – Oudeberg Bestuiwing Ceres - Paarl	1	1
				2	0
				3	0
				4	0
				5	0
				6	1
				7	0
				8	4
				9	0
				10	3
Dawid Smit	03/99	Robertson	Bye bestuiwing Wolseley	1	0
				2	0
				3	0
				4	0
				5	2
				6	0
				7	0
				8	1
				9	0
Francois du Toit	03/99	Worcester	Bestuiwing Villiersdorp - Touwrivier	1	12
				2	22
				3	20
				4	7
				5	7
				6	5
				7	18
				8	4

Francois du Toit	03/99	Worcester		1	10
				2	11
				3	4
				4	14
				5	3
				6	4
				7	11
				8	23
John Moodie		Heidelberg	Pollination Langkloof - Heidelberg	1	0
				2	0
				3	0
				4	4
				5	0
				6	2
Derek Hugo		Hopefield	Sedentary	1	30
				2	0
				3	0
				4	2
				5	0
				6	1
				7	0
				8	0
				9	0
				10	1
Dawid Smit	03/99	Robertson	From Robertson/ Bonnievale?	1	0
				2	0
				3	0
				4	0
				5	0
Robert Post	02/99	Wolseley	Wolseley	1	6
				2	9
				3	15
				4	4
			Warme Bokkeveld	5	0
Alvin Hayes	23/04/99	Kuilsrivier		1	4
				2	1
				3	3
				4	1
				5	0
				6	3
				7	0
				8	2
				9	9
				10	2
				11	10
				12	3
				13	22
				14	0
				15	3
				16	3
				17	0
				18	0
				19	12
				20	0
Mike Kotze		Stillewater		1	12
				2	13
				3	0
				4	4
				5	13
				6	0
				7	9
				8	2
				9	3
				10	12

Nico Langenhoven	28/04/99	Malmesbury		1	5
				2	5
				3	5
				4	5
				5	3
				6	5
				7	5
				8	5
				9	3
				10	3
Mike Kotze	06/05/99	Atlantis		1	1
				2	0
				3	0
				4	0
				5	1
				6	0
				7	0
				8	1
				9	2
				10	0
Rolf Kriebel	11/05/99	Joostenberg-vlakte	Bye op Koekenaap	1	0
				2	0
				3	0
				4	0
O B	13/05/99	Welgevallen		1	0
				2	4
				3	12
				4	0
				5	2
Coenie Jones (Marinus van Eden)	10/99	Vredendal	Lutzville	1	0
				2	0
				3	1
Renier Engelbregcht	10/99	Koekenaap		4	0
				5	0
				6	0
				7	0
				8	0
Ben Barnard	10/99	Koekenaap		9	0
				10	0
				11	0
				12	0
				13	0
Pieter Du Plessis	10/99	Lutzville		14	1
				15	0
				16	1
Calitz	10/99	Lutzville Vaalkrans		17	0
				18	0
				19	0
				20	0
				21	0
Van der Merwe	10/99	Vredendal		22	0
				23	0
				24	0
				25	0
Dirk van Zyl	10/99	Vredendal		26	0
				27	1?
				28	0
				29	0
				30	0
				31	0

Dirk van Zyl	10/99	Lutzville		32	0
				33	0
				34	0
				35	0
				36	0
				37	0
Ds van der Heever	10/99	Lutzville		38	0
				39	0
				40	11
Carstens	15/09/99	Koekenaap		1	0
				2	0
Coenie Jones	15/09/99	Koekenaap		1	0
				2	0
				3	0
Bos	15/09/99	Koekenaap		1	0
Rolf Kriebel	15/09/99	Koekenaap		1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
				9	0
				10	0
				11	0
Van der Merwe	15/09/99	Koekenaap		1	0
Spangenberg / Visagie	11/99	Koekenaap	Witwal	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
			Plaas	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
K van Niekerk	11/99	Kenhardt	Kokerboomwoud	1	0
				2	0
				3	0
				4	0
				5	0
W A Burger	11/99	Kenhardt	De Bokke	1	0
				2	0
				3	0
				4	0
Kraai van Niekerk	11/99	Kenhardt	Rugseer Klipkraal	1	0
				2	0
				3	0
				4	0
				5	0
			Huis	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0

Kraai van Niekerk	11/99	Kenhardt	Tenk	1	0
				2	0
				3	0
			Soutrivier	1	0
				2	0
				3	0
Stef du Toit	11/99	Citrusdal	Buite dorp Citrus	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
Ben	11/99	Keimoes			
				1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
K Brink	11/99	Keimoes	Koppie		
				1	0
				2	0
				3	0
				4	0
K Brink	11/99	Keimoes	Plaas	1	0
				2	0
				3	0
				4	0
				5	0
Agenbach	11/99	Kakamas		1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
O’ Kennedy	11/99	Niewoudtville	Bloekombos	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
				9	0
				10	0
				11	0
Neethling	23/03/99	Riviersonderend	Sedentary	1	32
				2	9
				3	1
				4	1
				5	30
				6	26
				7	14
				8	2
				9	3
				10	4

H Swart	23/03/99	Albertinia	Alle bye plaaslik gevang	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
V C Gerber	23/03/99	Albertinia	Sedentary	1	2
				2	0
				3	0
				4	1
				5	0
				6	0
				7	1
				8	0
				9	1
				10	0
Barkhuizen	24/03/99	Langkloof	Sedentary	1	2
				2	6
				3	4
				4	27
				5	1
				6	5
				7	6
				8	3
				9	1
Holtzhauzen	24/03/99	Ladismith	Algerynskraal I	1	10
				2	6
				3	0
				4	1
				5	0
				6	1
				7	0
Holtzhauzen	24/03/99	Ladismith	Algerynskraal II	1	6
				2	4
				3	1
				4	0
				5	19
				6	14
				7	6
				8	5
				9	10
Oberholster		Ladismith	Naby Holtzhauzen	1	22
				2	35
				3	3
				4	0
				5	1
				6	2
				7	6
				8	10
				9	8
				10	0
Charlotte Bye	03/99	Montagu	Sedentary	1	0
				2	2
				3	0
				4	1
				5	0
				6	0
				7	0
				8	0
				9	35
				10	0

Fouche	03/99	Montagu		Sedentary	1	0
					2	1
					3	4
					4	4
					5	0
					6	2
					7	3
					8	0
Nico Langenhoven	15/12/99	Paarl		Permanent	1	10
					2	21
					3	19
					4	9
					5	32
= L3					6	10
					7	19
					8	3
					9	36
					10	26
					11	10
					12	13
					13	39
					14	29
					15	15
					16	43
					17	17
					18	6
					19	7
					20	16
					21	30
					22	11
Rolf Kriebel	17/12/99	Joostenburg		Philadephia/ Alexandria	1	51
					2	13
					3	22
					4	13
					5	45
= K3					6	26
					7	23
					8	24
					9	6
					10	19
					11	58
					12	34
					13	29
					14	12
					15	15
					16	8
					17	11
					18	18
					19	67
					20	16
					21	19
					22	10
					23	27
					24	12
					25	6
					26	45
					27	21
					28	13
					29	17
					30	38
					31	26
					32	22
PPR1	15/12/99	Elsenburg	PPRI (1)		1	8
					2	6
					3	6
					4	32
= P3					5	8
					6	14
					7	21
					8	4
					9	11
					10	19

PPR1	15/12/99	Elsenburg	PPRI (2)		1	5
					2	16
					3	13
					4	3
= P3					5	16
					6	15
					7	7
					8	11
					9	3
Mark Myburgh	11/99	Richmond		Trapped in Ixopo July 1998	1	140
					2	84
					3	65
					4	280
					5	175
		Richmond (2) Wondergeluk		Trapped in Richmond June-July 1998	1	119
					2	73
					3	130
					4	78
					5	180
					6	34
					7	43
					8	65
					9	111
					10	73
		Ixopo		Trapped Ixopo	1	61
					2	24
					3	8
					4	15
Curtis Fulton	11/99	Richmond		Richmond cold boxes	1	14
					2	33
					3	8
					4	33
					5	13
					6	14
Reg Leveridge	11/99	Mooirivier		Feral colony	1	35
Rod Arbuckle	11/99	Richmond (1)		Established colonies	1	18
					2	7
					3	19
					4	7
					5	35
					6	43
		Richmond (2)		Established colonies	1	54
					2	48
					3	21
					4	47
					5	31
					6	24
Colin Campbell-Cilliers	11/99	Kloof		Sedentary	1	9
William Urquhart	11/99	Cedara		Sedentary	1	11
					2	15
					3	16
					4	31
					5	31
					6	40

Mark Myburgh	11/99	Richmond (3)		1	147
				2	71
				3	56
				4	60
				5	102
				6	66
				7	166
				8	138
				9	56
				10	60
				11	94
				12	25
				13	52
				14	72
				15	106
				16	39
				17	37
				18	51
				19	29
				20	59
				21	29
				22	72
				23	30
				24	24
				25	18
				26	66
				27	48
				28	38
				29	37
				30	107
				31	60
Stephan Hartung	20/04/99	Heidelberg 1	Recent traps from Piet Retief	1	14
				2	22
				3	138
				4	23
				5	53
				6	16
				7	83
				8	48
				9	6
				10	21
				11	68
				12	29
				13	25
				14	29
				15	20
				16	42
				17	28
				18	32
				19	12
				20	13
Stephan Hartung	20/04/99	Heidelberg 2	Recent traps from Piet Retief	1	4
				2	21
				3	7
				4	2
				5	15
				6	41
				7	35
				8	45
				9	8
				10	11
				11	2
				12	2
				13	16
				14	115
				15	24
				16	32
				17	17
				18	4
				19	13
				20	12

Stephan Hartung	20/04/99	Heidelberg 3	Recent traps from Piet Retief	1	21
				2	63
				3	96
				4	34
				5	22
				6	53
				7	91
				8	74
				9	85
				10	11
				11	35
				12	38
				13	21
				14	47
				15	29
				16	218
				17	92
				18	121
				19	52
				20	2
Stephan Hartung	20/04/99	Heidelberg 4	Recent traps from Piet Retief	1	166
				2	75
				3	53
				4	130
				5	39
				6	21
				7	71
				8	7
				9	43
				10	22
				11	135
				12	42
				13	11
				14	10
				15	5
				16	40
				17	22
				18	57
				19	16
				20	35
Tony Bester	07/09/99	Quartzberg (White River)		1	0
				2	0
				3	0
				4	0
Fred Bence	07/09/99	Lisbon		1	0
				2	0
				3	0
				4	0
Stefan Hartung	28/10/99	Heidelberg	Recent traps	1	12
				2	8
				3	10
				4	8
				5	14
				6	6
				7	5
				8	12
				9	5
				10	7
				11	5
				12	10
				13	11
				14	21
				15	27
				16	30
				17	15
				18	19
				19	5
				20	7
				21	3
				22	6
				23	2

Stefan Hartung	28/10/99	Heidelberg	Recent traps	24	3
				25	4
				26	6
				27	1
				28	3
				29	2
				30	3
				31	1
				32	3
Eddy Lear	12/99	Jhb		1	Y
Rolf Kriebel	19/07/99	Joostenberg-Vlakte		1	6
				2	38
				3	28
				4	3
				5	24
				6	18
				7	8
				8	11
				9	18
				10	9
				11	21
				12	52
				13	12
				14	13
				15	16
				16	24
				17	13
				18	17
				19	21
				20	23
Clay Whittal	09/07/99	George	Oakhurst	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
				9	0
				10	0
			Landwood	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
				9	0
				10	0
			Gouritz	1	0
				2	0
				3	0
				4	0
				5	0
Mike Kotze	17/06/99	Melkbosstrand		1	5
				2	17
				3	14
				4	6
				5	9
				6	10
Koos van der Merwe	9/2/99	Pretoria		1	5
				2	6
Danie du Toit	9/1/99	Pretoria		1	0
				2	0
				3	0
				4	0

Dawid Swart	9/9/99	Pretoria		1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
Martin Johannsmeier	19/8/99	Pretoria		1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
				9	0
Hennie du Toit	30/08/99	Christiana	Die vlei	1	0
				2	0
				3	0
				4	0
				5	0
Hennie du Toit	30/08/99	Christiana	Waterwerke	1	0
				2	0
				3	0
				4	0
				5	0
			Stasie	1	0
				2	0
				3	0
				4	0
				5	0
				6	0

2000-2002 surveys & *ad hoc* samples: Beekeeper colonies only

A Lazaries	11/03/00	Pinelands	New swarm	1	30
Derrick Hugo	07/02/00	Hopefield		1	9
				3	6
				5	27
				6	6
				11	7
				12	9
				13	1
				16	10
				17	7
				19	14
				20	9
Stephen Smit	4/2/00	Bredasdorp		1	1
				2	1
				3	6
				4	7
				5	15
				6	13
				7	10
				8	4
				9	20
				10	15
				11	60
				12	15
				13	5
				14	79
				15	14
				16	7
				17	3
				18	33

Stephen Smit	4/2/00	Bredasdorp		19	43
				20	0
				21	6
				22	38
				23	7
				24	6
				25	44
				26	2
				27	67
				28	55
				29	30
				30	3
				31	7
				32	2
				33	20
				34	18
				35	21
				36	37
				37	9
				38	3
				39	4
				40	16
				41	18
				42	14
				43	5
				44	2
Jim Pullinger	22/09/00	Ermelo		1	15
				2	13
				3	73
				4	36
				5	21
				6	10
				7	12
				8	0
				9	5
PPRI	01/09 00	Elim		1	15
				2	17
				3	21
				4	7
				5	24
				6	4
				7	11
				8	8
				9	4
				10	8
PPRI	07/09/00	UWC		0	0
				0	0
PPRI	20/06/00	Stellenbosch	Bye Huis	44	5
				3	6
				10	8
				1	0
				17	4
				25	26
			Klipbank	84	46
				55	24
				70	30
				73	5
				75	42
				9	27
				8	35
			Khan	17	19
				13	25
				20	29
				12	58
				19	71
				16	6
				15	68
				11	43

PPRI	20/06/00	Elsenberg	PPRI (1)	Verste Plek	1	6
					116	9
					67	6
					110	5
= P4					115	7
					9	25
					140	10
					80	4
					119	49
			PPRI (2)	Rivier II	44	2
					4	1
					6	1
					94	2
= P4					96	2
					22	3
					33	5
					107	6
					120	8
					89	92
				Rivier I	50	7
					64	5
					20	4
					23	4
					150	7
					9	6
					160	19
					2	1
				Paradyskloof	150	4
					151	0
					152	0
					153	2
					154	1
					155	0
					156	5
					157	0
					158	5
					159	6
					160	0
					161	2
				Rondewal	120	7
					110	1
					90	51
					80	2
					116	15
					115	7
					119	8
					84	11
Charles Friderichs	17/03/00	Fort Beaufort			A	0
					B	0
					C	0
					D	0
					E	0
					F	0
					G	0
					H	0
					I	0
		Port Alfred			A	0
					B	0
					C	0
					D	0
		Grahamstown			A	3
Charles Friderichs	29/02/00	Grahamstown			1	0
					2	2

Charles Friderichs	25/05/00	Port Alfred		1	0
				2	1
				3	0
				4	0
				5	0
				6	0
				7	0
				8	0
				9	0
				10	0
Charles Friderichs	25/08/00	Port Alfred		1	0
				2	0
			New traps	1	0
				2	0
				3	0
			From Grahamstown	1	1
Henrik Pansegrow	05/09/00	Barclay East		1	0
				2	0
				3	0
Henrik Pansegrow	05/09/00	Queenstown		1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	0
Rolf Kriebel	10/10/00	Koekenaap		1	39
				2	10
				3	30
PPRI	02/10/00	Elsenburg	6-12 month swarms	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
				7	5
				8	6
				9	3
PPRI	02/10/00	Elsenburg	6-12 month swarms	10	15
				11	10
				12	5
Danie Fourie	31/10/00	Leeu Gamka		1	9
				2	62
Andre de Jager	01/11/00	Albertinia	3 year old swarms	1	4
				2	0
				3	10
				4	90
				5	0
				6	33
				7	5
				8	3
				9	2
Kraai van Niekerk	02/11/00	Keimoes		1	0
				2	0
Andy Worrall	08/04/00	Boksburg		1	8
				2	3
				3	17
				4	5
				5	1
				6	13
				7	0
				8	4
				9	5
				10	1
				11	1

Harry Viljoen	08/04/00	Benoni	1	N
			2	Y
			3	Y
			4	Y
			5	Y
			6	Y
			7	Y
			8	Y
			9	Y
			10	Y
			11	Y
			12	Y
			13	Y
			14	Y
			15	Y
Tinus de Klerk	08/07/00	De Wild (Brits)	1	4
			2	3
			3	9
			4	10
			5	8
			6	2
			7	14
			8	17
			9	14
			10	3
			11	3
Hendrik Kelly	08/09/00	Soutpan (50km N/W Pta)	1	2
			2	20
			3	21
			4	11
			5	33
			6	4
			7	3
			8	20
			9	18
			10	38
			11	11
			12	25
			13	10
			14	16
			15	7
B Wiese	12/09/00	Rietondale (Pta)	1	8
			2	3
			3	3
			4	2
			5	8
			6	1
			7	4
			8	7
			9	7
Volkmer Bohmer	13/09/00	Springs	1	0
			2	1
			3	0
			4	1
			5	0
			6	0
			7	1
			8	2
			9	0
			10	1
			11	2

Volkmer Bohmer	13/09/00	Boksburg		1	5
				2	3
				3	18
				4	2
				5	29
				6	27
				7	12
				8	14
				9	13
				10	8
				11	5
				12	8
				13	5
				14	4
				15	40
				16	26
				17	11
				18	19
				19	15
				20	6
L Vlok	15/09/00	Ogies		1	24
				2	11
				3	9
				4	15
				5	4
				6	7
				7	14
L Vlok	15/09/00	Alberton (1)		1	9
				2	11
				3	15
				4	33
				5	8
				6	3
L Vlok	15/09/00	Alberton (2)	Traps from Piet Retief	1	15
				2	0
				3	12
				4	4
				5	9
				6	7
				7	2
Michael Lutz	27/09/00	Nelspruit (1)		1	1
				2	0
				3	0
				4	2
Michael Lutz	27/09/00	Nelspruit (2)		1	0
				2	0
				3	0
				4	0
				5	0
Michael Lutz	27/09/00	Nelspruit (3)		1	0
				2	0
				3	0
				4	0
Fred Bence	28/09/00	White River		1	0
				2	0
				3	0
				4	0
				5	0
				6	0
James Williams	05/10/00	Rayton		1	7
				2	2
				3	22
				4	11
				5	9
				6	1
				7	13

Theuns Engelbrecht	7/12/00	Douglas			1	17
					2	32
					3	2
					4	1
					5	0
					6	2
					1	23
					2	2
					3	0
					4	1
					5	0
					6	5
					7	28
					8	16
Bob Liechtenstein	13/12/00	Bloemfontein			1	7
					2	0
					3	0
					4	56
					5	23
					6	1
IJ Jordaan	14/12/00	Kroonstad			1	2
					2	0
					3	2
					4	0
					5	1
					6	1
					7	0
					8	18
PPRI	11/01/2001	Stellenbosch		Rivier I	1	1
					2	0
					3	3
					4	1
					5	0
					6	0
					7	8
					8	0
					9	4
					10	2
					11	0
					12	3
				Klipbank	1	6
					2	8
					3	2
				Paradyskloof	1	1
					2	0
					3	2
				Rondawel	1	12
					2	0
					3	0
					4	5
					5	1
					6	12
					7	10
			PPRI (1)	Verste Plek	1	1
					2	4
					3	4
					4	7
= P5					5	0
					6	5
					7	0
					8	1
					9	23

PPRI	11/01/01	Elsenburg	PPRI (2)	Rivier I	1	0
					2	44
					3	2
= P5					4	1
					5	3
					6	16
					7	8
					8	0
Rolf Kriebel	17/01/01	Joostenburg			1	21
					2	3
					3	6
					4	3
					5	2
= K4					6	24
					7	5
					8	17
					9	10
					10	11
					11	1
					12	5
					13	1
					14	12
					15	0
					16	16
					17	25
					18	12
					19	1
					20	8
					21	5
					22	2
					23	2
					24	19
					25	32
					26	1
					27	2
					28	9
					29	4
					30	15
Nico Langenhoven	22/01/01	Paarl			1	2
					2	12
					3	2
					4	6
					5	1
					6	0
= L4					7	4
					8	6
					9	22
					10	14
					11	4
					12	5
					13	3
					14	9
					15	10
					16	2
K Spanenberg	12/03/01	Calvinia			1	6
					2	0
					3	12
					4	3
B O' Kennedy	14/03/01	Nieuwoudtville			1	0
					2	0
					3	9
					4	3
					5	0
					6	3
Tony Bester	28/9/01	Nelspruit			1	17
					2	5
					3	2
					4	2
					5	16

Tony Bester	29/9/01	White River		1	0
				2	0
				3	6
				4	5
				5	28
				6	3
PPRI	4/02/02	Elsenburg	PPRI (1)	1	13
				2	2
				3	0
				4	0
				5	1
= P6				6	0
				7	4
				8	8
			PPRI (2)	1	2
				2	2
				3	1
				4	0
= P6				5	1
				6	0
				7	6
Rolf Kriebel	9/02/02	Joostenberg		1	7
				2	14
				3	2
				4	0
				5	0
= K5				6	3
				7	0
				8	2
				9	5
				10	18
				11	2
				12	4
				13	7
				14	8
				15	3
				16	12
				17	8
				18	7
				19	3
				20	0
				21	3
				22	0
				23	2
				24	1
				25	6
				26	1
				27	25
				28	15
				29	3
				30	0
				31	7
				32	4
				33	10
Nico Langenhoven	15/02/02	Paarl		1	11
				2	1
				3	2
				4	1
				5	0
= L5				6	0
				7	4
				8	0
				9	6
				10	0
				11	0
				12	7
				13	16
				14	13

Charles Friderichs	10/03/2002	Port Alfred		1	37
				2	23
				3	11
				4	6
				5	56
				6	34
				7	56
				8	23
				9	12
				10	5
				11	34
				12	35
				13	22
				14	12
				15	4
				16	48
				17	17
				18	13
				19	23
				20	31
				21	42
				22	23
				23	25
				24	13
				25	18
				26	11
Charles Friderichs	11/03/2002	Grahamstown		1	16
				2	24
				3	29
				4	11
				5	6
				6	9
				7	10
				8	23
				9	31
				10	21
				11	18
				12	15
				13	8
				14	26
Charles Friderichs	11/03/2002	Fort Beaufort	A	1	0
				2	0
				3	0
				4	0
				5	0
				6	0
			B	1	0
				2	0
				3	0
				4	0
				5	2
				6	0
			C	1	4
				2	7
				3	0
				4	3
				5	2
				6	0
				7	1
Frank Steinhobel	25/08/02	Swartwater		1	14
				2	13
Charlie Gerber	25/08/02	Louis Trichardt		1	11
				2	9
				3	0
				4	6
				5	2

Charlie Gerber	26/08/02	Levuhu	1	2
			2	3
			3	4
			4	2
Gerald Beverly	09/09/02	Komatipoort	1	14
			2	0
			3	0
			4	4
Piet Smit	12/12/02	Beit Bridge	1	0
			2	4
			3	6
			4	21
			5	2

APPENDIX II:
COLONY MORTALITY CAUSED BY THE VARROA MITE

Key

- Frames of bees are scored 1-10 for the brood box, 10+ for one full super of bees, and 10++ for two supers of bees.
- Frames of worker brood and drone brood are estimated in one-eighth quantities per frame, and added for each colony.
- Queens are denoted as present or absent. Where marked (ie "pink"), this is indicated. The presence and quantity of queen cells is indicated.
- If varroa are present on the queen, the number of varroa is indicated.
- The percentage of dead pupae (ie open pink-eye pupae) is indicated.
- Workers without wings, visible varroa on bees, obvious dark "*capensis*" bees, and other disease symptoms (European Foulbrood, chalkbrood, nosema) are each indicated on a scale of 0 to 5.
- The presence of laying worker eggs is indicated, as is whether or not the colony was treated with two Bayvarol strips.
- The varroa load of the colonies (varroa per 100 bees), as determined by the hot water method and using bees from the brood box, is indicated.

Kwazulu-Natal

Table 1 Beekeeper: Mark Myburgh Site: Haywood-Butt (Richmond – KZN) Date:08/03/99

Colony Number	Frames of Bees	Frames of worker brood	Frames of drone brood	Queen and/or Queen cells	Number of varroa on queen	% of dead pupae	Workers with no wings (0-5)	Visible varroa on workers (0-5)	Laying worker eggs	Obvious "dark" bees (0-5)	Other disease symptoms (0-5)	Bayvarol treatment	Varroa load (mites per 100 bees)
1	1	0.5	0	Pink	0	55	3	3	0	0	0	Y	4.6
2	1	0.25	0	Pink	0	40	2	3	0	0	0	N	23.1
3	1	0.75	0	Pink	0	20	2	3	0	0	0	Y	8.1
4	2.5	2.5	0	Pink	0	10	2	3	0	0	2	N	15.2
5	2	3.5	0	Pink	1	20	1	1	0	0	2	Y	18.6
6	3	4.5	0	Pink	0	30	2	2	0	0	2	N	15.6
7	3	2.5	0	Pink	0	10	2	2	0	0	1	Y	8.8
8	1.5	2.5	0	Pink	0	20	3	3	0	0	1	N	11.1
9	1	3	0	Pink	4	20	3	3	0	0	1	Y	18.6
10	8	5.5	1.5	Pink	0	10	3	3	0	0	1	N	11.6

Notes: 25% of colonies in this apiary have died in the past three weeks. Most colonies were trapped 12 months ago.

Table 2 Beekeeper: Mark Myburgh Site: Psycho (Richmond – KZN) Date:08/03/99

Colony Number	Frames of Bees	Frames of worker brood	Frames of drone brood	Queen and/or Queen cells	Number of varroa on queen	% of dead pupae	Workers with no wings (0-5)	Visible varroa on workers (0-5)	Laying worker eggs	Obvious "dark" bees (0-5)	Other disease symptoms (0-5)	Bayvarol treatment	Varroa load (mites per 100 bees)
1	2	3.5	0	Pink	0	20	1	2	0	0	0	Y	1.7
2	3	2.5	0	Pink	0	20	2	2	0	0	0	Y	2.1
3	3	3.5	0.125	5 QC	-	30	1	1	0	0	0	N	14.5
4	6.5	7.5	0.5	Pink	0	10	1	1	0	0	0	Y	7.6
5	6	7	1.25	Pink	0	25	2	1	0	0	0	N	10.2
6	3	3.5	0	Pink	0	20	1	1	0	0	0	N	15.9
7	4	4.5	0	Pink	0	2	0	0	0	0	0	Y	5.8
8	4	3.5	0.5	Pink	0	2	0	0	0	0	0	N	11.7
9	3.5	3.5	0	Pink	0	5	0	0	0	0	0	Y	11.7

Notes: Colonies 8 & 9 are young swarms; nematodes in the sieves of a number of colonies.

Table 3 Beekeeper: Eric Brown Site: Waters' Meet (Richmond – KZN) Date:11/03/99

Colony Number	Frames of Bees	Frames of worker brood	Frames of drone brood	Queen and/or Queen cells	Number of varroa on queen	% of dead pupae	Workers with no wings (0-5)	Visible varroa on workers (0-5)	Laying worker eggs	Obvious "dark" bees (0-5)	Other disease symptoms (0-5)	Bayvarol treatment	Varroa load (mites per 100 bees)
1	6	2	0	Y							1	Y	6.1
2	10	4	0	Y							1	Y	38.6
3	6	2	0	Y							1	Y	4.7
4	10	3	0	Y							1	Y	5.9
5	3	0	0	3QC							4	Y	7.5
6	10	5	0	Y							1	Y	10.3
7	10	6	0	Y							1	Y	5.2
8	10	4	0	Y							1	Y	9.2
9	10	5	0	Y							1	Y	4.8

Table 4 Beekeeper: Eric Brown Site: Waters' Meet (Richmond – KZN) Date:11/03/99

Colony Number	Frames of Bees	Frames of worker brood	Frames of drone brood	Queen and/or Queen cells	Number of varroa on queen	% of dead pupae	Workers with no wings (0-5)	Visible varroa on workers (0-5)	Laying worker eggs	Obvious "dark" bees (0-5)	Other disease symptoms (0-5)	Bayvarol treatment	Varroa load (mites per 100 bees)
11	10	6	0	Y							1	N	6.5
12	10	5	0	Y							1	N	4.4
13	10	4	0	Y							1	N	6.1
14	10	4	0	Y							1	N	0.1
15	10	7	0	Y							1	N	4.5
16	10	5	0	Y							1	N	5.0
17	10	5	0	Y							1	N	5.4
18	10	4	0	Y							1	N	3.6

Table 5 Beekeeper: Rod Arbuckle Site: Homestead (Richmond – KZN) Date:09/03/99

Colony Number	Frames of Bees	Frames of worker brood	Frames of drone brood	Queen and/or Queen cells	Number of varroa on queen	% of dead pupae	Workers with no wings (0-5)	Visible varroa on workers (0-5)	Laying worker eggs	Obvious "dark" bees (0-5)	Other disease symptoms (0-5)	Bayvarol treatment	Varroa load (mites per 100 bees)
1	7	0.25	0	N	-	10	1	1	Y	3	0	N	1.7
2	7	5.25	1	Y	0	2	1	1	N	0	1	Y	3.5
3	8	5.5	0.75	Y	0	5	2	1	N	1	1	N	1.8
4	8	4	0.5	Y	3	2	2	2	N	0	0	Y	3.7
5	2.5	1.25	0	Y	0	10	0	0	N	0	0	N	1.5
6	9	5	1.5	Y	0	0	0	0	N	0	0	Y	2.7
7	8	4.25	1.5	Y	0	0	0	1	Y	1	0	N	1.0
8	8	6.25	0.75	Y	0	0	0	0	N	0	0	Y	0.7
9	4	2.5	0	Y + 2QC	0	2	0	0	Y	3	1	N	9.6
10	6	3	1.5	Y	0	5	0	0	N	2	0	Y	2.1
11	7	5.5	0.5	Y	0	1	0	0	N	0	0	N	0.5
12	4	3.5	0.5	Y	0	5	0	2	N	0	0	Y	0.6
13	1	2.75	0	Y	0	30	1	2	N	1	0	N	3.1

Notes: There were 30 colonies in the apiary. The 16 colonies that were trapped 15-18 months ago are all dead (empty boxes); colonies 1-8 are 6-8 months old; and colonies 9-13 are 12 months old. Colonies 8, 9, & 12 have masses of "dead open pupae', but no other "varroa symptoms". A sample collected from colony 12 indicated the "dead open pupae" (both drones and workers) to mostly have attached varroa. Colony 13 had masses of dead brood in cells.

Table 6 Beekeeper: Mark Myburgh Site: Haywood-Butt (Richmond – KZN) Date:23/06/99

Colony Number	Frames of Bees	Frames of worker brood	Frames of drone brood	Queen and/or Queen cells	Number of varroa on queen	% of dead pupae	Workers with no wings (0-5)	Visible varroa on workers (0-5)	Laying worker eggs	Obvious "dark" bees (0-5)	Other disease symptoms (0-5)	Bayvarol treatment	Varroa load (mites per 100 bees)
1	5	2	0	Pink	0	0	0	0	0	1	0	Y	0
2	1.5	0.5	0	Pink	0	0	0	0	0	0	0	N	1.1
3	1.5	1	0	Pink	0	0	0	0	0	1	0	Y	0
4	7	4.5	0.5	EC	-	0	0	0	0	3	0	N	0
5	10+	4.5	0.25	?	-	0	0	0	0	0	0	Y	0.2
6	8	3.25	0	Pink	0	2	0	0	0	1	0	N	3.5
7	10+	6.5	0.25	Pink	0	0	0	0	0	0	0	Y	0
8	10+	7.25	0.25	Pink	0	1	0	0	0	0	0	N	0.3
9	4	2.25	0.125	Pink +NQ	0+0	0	0	0	0	0	0	Y	0
10	10+	6.5	0.5	Pink	0	0	0	0	0	0	0	N	3.1

Table 7 Beekeeper: Mark Myburgh Site: Psycho (Richmond – KZN) Date:25/06/99

Colony Number	Frames of Bees	Frames of worker brood	Frames of drone brood	Queen and/or Queen cells	Number of varroa on queen	% of dead pupae	Workers with no wings (0-5)	Visible varroa on workers (0-5)	Laying worker eggs	Obvious "dark" bees (0-5)	Other disease symptoms (0-5)	Bayvarol treatment	Varroa load (mites per 100 bees)
1	8	4.75	0.25	Pink	0	1	0	0	0	0	0	Y	0
2	10	5.5	1	Pink + 5C	0	1	0	0	0	0	0	Y	0
3	4	2.5	0	YQ	0	0	0	0	0	0	0	N	1.7
4	10+	6.5	0.75	Pink + 3V	0	0	0	0	0	0	0	Y	0.2
5	10+	5.5	1.25	Pink	0	0	0	0	0	0	0	N	1.2
6	7.5	5.25	0.5	Pink	0	0	0	0	0	0	0	N	0
7	10+	5.25	1	Pink	0	0	0	0	0	0	0	Y	0
8	9	5	1	Pink + 3C	0	0	0	0	0	0	0	N	2.7
9	10+	7.5	1	Pink	0	0	0	0	0	0	0	Y	0

Notes: Sealed queen cells in both colonies 2 & 8. Both colonies ready to swarm. All queen cells removed. Three virgin queens, as well as the Pink queen, in colony 4. Pink queen will swarm.

Table 8 Beekeeper: Eric Brown Site: Waters' Meet (Richmond – KZN) Date:24/06/99

Colony Number	Frames of Bees	Frames of worker brood	Frames of drone brood	Queen and/or Queen cells	Number of varroa on queen	% of dead pupae	Workers with no wings (0-5)	Visible varroa on workers (0-5)	Laying worker eggs	Obvious "dark" bees (0-5)	Other disease symptoms (0-5)	Bayvarol treatment	Varroa load (mites per 100 bees)
1	10+	4.75	0	Y	0	2	0	0	0	0	0	Y	0
2	9	4.5	0	Y	0	5	0	0	0	0	5	Y	0
3	10+	4.5	0.125	Y	0	1	0	0	0	0	0	Y	0
4	10	4.25	0.25	Y	0	5	0	0	0	0	0	Y	0
5	10++	7.5	0.75	Y	0	1	0	0	0	0	0	Y	0
6	10+	5	1.5	?	-	0	0	0	0	0	0	Y	0
7	7	2.75	0.5	Y	0	0	0	0	0	0	0	Y	0
8	9	6.5	0	Y	0	0	0	0	0	0	0	Y	0
9	4	1	0	Y	0	0	0	0	0	0	0	Y	0

Notes: Both colonies 3 & 8 have healthy, new queens. Colony 2 is very heavily infected with chalkbrood; worst ever seen in South Africa. Literally thousands of cocoons. But the bees are removing them and will recover. A sample was collected. Colony seven has swarmed; now with new queen.

Table 9 Beekeeper: Eric Brown Site: Waters' Meet (Richmond – KZN) Date:24/06/99

Colony Number	Frames of Bees	Frames of worker brood	Frames of drone brood	Queen and/or Queen cells	Number of varroa on queen	% of dead pupae	Workers with no wings (0-5)	Visible varroa on workers (0-5)	Laying worker eggs	Obvious "dark" bees (0-5)	Other disease symptoms (0-5)	Bayvarol treatment	Varroa load (mites per 100 bees)
11	Dead												
12	Dead												
13	Dead												
14	Dead												
15	Dead												
16	10+	4.25	0	Y	0	2	0	0	0	0	0	N	0
17	Dead												
18	Dead												

Notes: Only one of the untreated colonies survives, and this appears very healthy. Perhaps significant that one of untreated colonies close to treated colonies (the one that survived). The rest were more distant; some 100 metres away, down a slope, and separated by a number of rows of trees. All "dead" colonies simply empty; no dead bees or dead brood remaining.

Table 10 Beekeeper: Rod Arbuckle Site: Homestead (Richmond – KZN) Date:25/06/99

Colony Number	Frames of Bees	Frames of worker brood	Frames of drone brood	Queen and/or Queen cells	Number of varroa on queen	% of dead pupae	Workers with no wings (0-5)	Visible varroa on workers (0-5)	Laying worker eggs	Obvious "dark" bees (0-5)	Other disease symptoms (0-5)	Bayvarol treatment	Varroa load (mites per 100 bees)
1	3	3 Sc	0	N	-	0	0	0	Y+++	5	1	N	0
2	7.5	4 Sc	0	N	-	0	0	0	Y+	3	1	Y	0
3	6	4 Sc	0	N	-	5	0	0	Y+	3	0	N	1.3
4	9	5.5	0.5	Y	0	0	0	0	0	1	0	Y	0
5	5	3.25	0	Y	0	5	0	0	Y	1	0	N	0.2
6	10	6 Sc	0	N	-	5	0	0	Y++	2	0	Y	0
7	5	6 Sc	0	N	-	0	0	0	Y+	2	0	N	0.2
8	10	5.25	0.5	Y	0	1	0	0	0	1	0	Y	0
9	2.5	1 Sc	0	N	-	5	0	0	Y	2	0	N	1.4
10	8	3.5 Sc	0	N	-	1	0	0	Y+	2	0	Y	0
11	10	6.25	0.75	Y	0	1	1	0	0	0	0	N	0
12	3	1	0	Y	0	0	0	0	0	2	0	Y	0.2
13	Dead											N	

Notes: Seven of the colonies are now queenless, with typical "Capensis Problem" symptoms. These colonies are expected to die, as are all others in the apiary, with no assistance from varroa. Colonies 6 & 9 may have young *capensis* queens; both have emerged queen cells. The small amount of disease present is EFB, typical of Capensis problems.

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Table 11 Beekeeper: Nico Langenhoven Site: Paarl Date:02/10/99

Colony Number	Queen	Queen cells	Frames of bees	Frames of worker brood	Bayvarol treatment	Varroa Load (mites per 100 bees)
PB1	Yes	No	8	4	No	4.0
PB2	Yes	No	10	4.75	No	10.5
PB3	Yes	No	6	2	No	7.6
PB4	Yes	No	8	2.5	No	3.6
PB5	Yes	No	10	4.25	No	12.8
PB6	Yes	No	7	2	No	4.0
PB7	Yes	No	5	0	No	7.6
PB8	Yes	No	10	2	No	1.0
PB9	No	Worker brood	6	0	No	18.0
PB10	Yes	No	10	3	No	8.7
PB11	Yes	No	9	4	No	4.0
PB12	Yes	No	7	2	No	5.2
PB13	Yes	No	7	1.5	No	13.0
PB14	Yes	No	10	4	No	9.7
PB15	Yes	No	10	3.5	No	6.0
PB16	Yes	No	10	3	No	14.3
PB17	Yes	No	10	3.5	No	6.8
PB18	Yes	No	6	3	No	3.0
PB19	Yes	No	8	3.5	No	2.3
PB20	Yes	No	7	1	No	6.4
PB21	Yes	No	8	2	No	10.0
PB22	Yes	No	9	3	No	3.7

Table 12 Beekeeper: Nico Langenhoven Site: Paarl-2 Date:03/10/99

Colony Number	Queen	Queen cells	Frames of bees	Frames of worker brood	Bayvarol treatment	Varroa Load (mites per 100 bees)
VB1	Yes	No	8	3	Yes	8.6
VB2	Yes	No	10	2.5	Yes	4.8
VB3	Yes	No	7	2	Yes	5.0
VB4	Yes	No	6	2.25	Yes	6.2
VB5	Yes	No	6	3.25	Yes	11.6
VB6	Yes	No	8	1.5	Yes	5.2
VB7	Yes	No	7	2	Yes	3.0
VB8	Yes	No	10	4.5	Yes	2.5
VB9	Yes	No	10	4.25	Yes	15.0
VB10	Yes	No	10	3.75	Yes	9.7
VB11	Yes	No	6	2	Yes	6.8
VB12	Yes	No	9	4	Yes	12.5
VB13	Yes	No	8	3.75	Yes	3.7
VB14	Yes	No	6	1.25	Yes	4.0
VB15	Yes	No	9	4.5	Yes	5.2
VB16	Yes	No	8	2.5	Yes	1.5
VB17	Yes	No	7	1.75	Yes	13.2
VB18	Yes	No	10	3.5	Yes	22.5
VB19	Yes	No	9	3	Yes	6.5

Table 13 Beekeeper: Nico Langenhoven Site: Paarl Date:15/01/00

Colony Number	Queen	Queen cells	Frames of bees	Frames of worker brood	Bayvarol treatment	Varroa Load (mites per 100 bees)
PB1	Dead				No	
PB2	Yes	1	10	2.5	No	34.0
PB3	Dead				No	
PB4	Yes	No	9	4	No	11.2
PB5	Yes	No	10	3	No	19.3
PB6	Yes	1	6	2	No	3.2
PB7	Dead				No	
PB8	Yes	No	8	2.5	No	4.6
PB9	Dead				No	
PB10	Yes	No	10	2	No	27.0
PB11	Yes	1	10	3.5	No	28.5
PB12	Yes	No	7	3	No	7.8
PB13	Yes	No	7	2.5	No	19.2
PB14	Yes	No	10	2	No	6.4
PB15	Yes	No	10	3	No	11.3
PB16	Yes	No	10	4.5	No	18.5
PB17	Yes	2	10	4	No	23.7
PB18	Yes	No	9	4.5	No	2.4
PB19	Yes	No	9	3.5	No	3.0
PB20	Dead				No	
PB21	Dead				No	
PB22	Yes	2	10	4	No	12.2

Table 14 Beekeeper: Nico Langenhoven Site: Paarl-2 Date:15/01/00

Colony Number	Queen	Queen cells	Frames of bees	Frames of worker brood	Bayvarol treatment	Varroa Load (mites per 100 bees)
VB1	Yes	No	3	0	Yes	0
VB2	Yes	No	10	5	Yes	0
VB3	Yes	No	10	6.5	Yes	0.6
VB4	Yes	No	10	4.5	Yes	0
VB5	Yes	No	10	7.5	Yes	0
VB6	Yes	No	10	6.5	Yes	0.9
VB7	Yes	No	10	4.5	Yes	0
VB8	Yes	No	10	5	Yes	0
VB9	Yes	No	10	5	Yes	0.2
VB10	Yes	No	10	5.5	Yes	0
VB11	Yes	No	10	4	Yes	0
VB12	Yes	No	10	6	Yes	0.2
VB13	Yes	No	10	5.25	Yes	0.3
VB14	Yes	No	10	5.5	Yes	0
VB15	Yes	No	10	5.25	Yes	0
VB16	Yes	No	10	5.25	Yes	0
VB17	Yes	No	10	5.5	Yes	0
VB18	Yes	No	10	5	Yes	1.2
VB19	Yes	No	10	4.5	Yes	0

APPENDIX III:
IMPACT OF THE VARROA MITE

Data collected by beekeepers in the Western Cape between March 1999 and September 2000 from colonies and apiaries that have not been given any anti-varroa treatment. Data is collected on the condition of the colonies and the level of varroa mites present in the colonies for this period.

NAME = Beekeepers' surname and initial; **MON** = Month during which data was recorded; **TIME** = number of months from when the first data was recorded for these colonies; **PLACE** = where the sample was taken; **REG** = where the sample was taken, divided into Boland (1), Helderberg (2), West Coast (3), Southern Cape (4), Eastern Cape (5) and Peninsula (6); **HIST** = recent history of the colony, as sedentary (S), of moved to a honey flow (H), or moved for commercial pollination (P); **COL** = colony number; **DEAD** = records the month that the hive was found empty, or the colony dead (DEAD), or if the colony has been lost (LOST); **HOW** = records the reason for the death/absence of the colony, as vandalism (V), ratel (R), fire (F) or unknown (U); **SIZE** = the number of brood frames of bees in the colony; **WORK** = the number of frames of worker brood in the colony; **DRONE** = the number of frames of drone brood in the colony; **POLL** = the number of frames of stored pollen in the colony; **QUE** = presence (Y) or absence (N) of the queen in the colony; **QC** = number of active queen cells present; **HON** = number of honey frames (deep frames) removed during this sampling period; and **VLOAD** = varroa load in the colony, measured as the number of varroa mites per one hundred workers bees removed from a brood frame of the colony, and analysed by the hot-water and sieve method. If data was not recorded during a particular sampling period, or not included on a submitted data sheet received from a beekeeper, this is indicated as NOT AVAILABLE (NA). In the case of VLOAD, NA often indicates that the colony was too small for a varroa sample to be collected.

NAME	MON	TIME	PLACE	REG	HIST	COL	DEAD	HOW	SIZE	WORK	DRONE	POLL	QUE	QC	HON	VLOAD
N. Ester	March	0	Grabouw	2	S	1			8	3.16	0.57	3.41	Y	0	0	0
N. Ester	March	0	Grabouw	2	S	2			14	5.5	0.57	1.96	Y	0	0	1.2
N. Ester	March	0	Grabouw	2	S	3			11	3.83	0.13	2	Y	0	0	0
N. Ester	March	0	Grabouw	2	S	4			11.5	4.5	0.66	2.41	Y	0	0	4.5
N. Ester	March	0	Grabouw	2	S	5			11	4.16	0.25	3.29	Y	0	0	0.2
N. Ester	March	0	Grabouw	2	S	6			12.5	2.54	0	2.29	Y	0	0	0.3
N. Ester	March	0	Grabouw	2	S	7			12.5	5	0.37	1.08	Y	0	0	1
N. Ester	March	0	Grabouw	2	S	8			8	3.49	0.5	2.12	Y	0	0	2.4
N. Ester	March	0	Grabouw	2	S	9			13.5	4.79	0.25	2.26	Y	0	0	1.3
N. Ester	March	0	Grabouw	2	S	10			13	2.33	0	1.5	Y	0	0	0.2
N. Ester	March	0	Grabouw	2	S	11			8	1.58	0	1.55	Y	0	0	1.5
N. Ester	March	0	Grabouw	2	S	12			12	3.83	0.25	2	Y	0	0	0.5
N. Ester	March	0	Grabouw	2	S	13			12.5	3.45	0.33	3.25	Y	0	0	0.7
N. Ester	March	0	Grabouw	2	S	14			9	3.5	0.25	2.65	Y	0	0	0.8
N. Ester	March	0	Grabouw	2	S	15			12.5	4	0.91	2.83	Y	0	0	6.5
N. Ester	March	0	Grabouw	2	S	16			10	2.45	0	2.83	Y	0	0	0.2
N. Ester	March	0	Grabouw	2	S	17			11	2.61	0	3.75	Y	0	0	0.4
N. Ester	March	0	Grabouw	2	S	19			12.5	3.08	0.91	3.46	Y	0	0	1.1
N. Ester	March	0	Grabouw	2	S	20			14	4.08	0	2.03	Y	0	0	0
N. Ester	March	0	Grabouw	2	S	21			12.5	2.83	0.13	3.3	Y	0	0	0
N. Ester	May	2	Grabouw	2	S	1			7	1.83	0	2.63	Y	0	0	0.8
N. Ester	May	2	Grabouw	2	S	2			10.5	2.05	0	0.75	Y	0	0	2
N. Ester	May	2	Grabouw	2	S	3			11.5	3.5	0	1	Y	0	0	1.2
N. Ester	May	2	Grabouw	2	S	4			10	3.14	0	2.58	Y	0	0	2
N. Ester	May	2	Grabouw	2	S	5			10.5	3.7	0	1.87	Y	0	0	2
N. Ester	May	2	Grabouw	2	S	6			13.5	3.12	0.5	3.8	Y	0	0	1.6
N. Ester	May	2	Grabouw	2	S	7			7	1.75	0	1.83	Y	0	0	6.4
N. Ester	May	2	Grabouw	2	S	8			10.5	2.63	0.13	3	Y	0	0	12

N. Ester	May	2	Grabouw	2	S	9			15	1.54	0	1.13	Y	0	0	3.2
N. Ester	May	2	Grabouw	2	S	10			7	0	0	0.5	Y	0	0	1.6
N. Ester	May	2	Grabouw	2	S	11			5	1.62	0	1.67	Y	0	0	2.8
N. Ester	May	2	Grabouw	2	S	12			9	1.66	0	0.5	Y	0	0	2
N. Ester	May	2	Grabouw	2	S	13			7	2	0	4.5	Y	0	0	1.6
N. Ester	May	2	Grabouw	2	S	14			5	2.33	0	0.92	Y	0	0	0.8
N. Ester	May	2	Grabouw	2	S	15			11	2.3	0	3.83	Y	0	0	4.4
N. Ester	May	2	Grabouw	2	S	16			8	1.53	0	4.42	Y	0	0	1.6
N. Ester	May	2	Grabouw	2	S	17			9	2.37	0.13	3.5	Y	0	0	0.8
N. Ester	May	2	Grabouw	2	S	19			8	2.3	0	3.3	Y	0	0	7.6
N. Ester	May	2	Grabouw	2	S	20			8	2.12	0	2.55	Y	0	0	0.4
N. Ester	May	2	Grabouw	2	S	21			5	1.62	0.13	3.83	Y	0	0	1.2
N.Ester	Aug	5	Grabouw	2	S	1			6	2	0.1	1.655	N	6	0	2.3
N. Ester	Aug	5	Grabouw	2	S	2			4	1.75	0	0.45	Y	0	0	5.8
N. Ester	Aug	5	Grabouw	2	S	3			6	2.5	0	0.5	Y	0	0	0.8
N. Ester	Aug	5	Grabouw	2	S	4			6	.	0	2.625	N	1	0	10.7
N. Ester	Aug	5	Grabouw	2	S	5			9	5.75	0.14	1.451	Y	0	0	4.3
N. Ester	Aug	5	Grabouw	2	S	6			10	5.2	0.5	2.491	Y	0	0	8.8
N. Ester	Aug	5	Grabouw	2	S	7			6	3.36	0	1.316	Y	0	0	12.4
N. Ester	Aug	5	Grabouw	2	S	8			6	3	0	1.45	Y	0	0	10.2
N. Ester	Aug	5	Grabouw	2	S	9			10	6.25	0.75	1.838	Y	0	0	1.5
N. Ester	Aug	5	Grabouw	2	S	10			9	3.5	0.25	0.625	Y	0	0	0
N. Ester	Aug	5	Grabouw	2	S	11			6	4.25	0	1.875	Y	0	0	1.3
N. Ester	Aug	5	Grabouw	2	S	12			9	3.75	0	0.906	Y	0	0	2.6
N. Ester	Aug	5	Grabouw	2	S	13			9	4.625	0.1	3.311	Y	0	0	2.7
N. Ester	Aug	5	Grabouw	2	S	14			5	2.5	0.125	1.241	Y	0	0	1.3
N. Ester	Aug	5	Grabouw	2	S	15			8	4.5	0.7	2.25	Y	0	0	5
N. Ester	Aug	5	Grabouw	2	S	16			5	0.3125	.	4.65	N	3	0	4.8
N. Ester	Aug	5	Grabouw	2	S	17			9	4.5	0.0625	1.2	Y	0	0	0.9
N. Ester	Aug	5	Grabouw	2	S	19			10	4	0.39	1.126	Y	0	0	2.7
N. Ester	Aug	5	Grabouw	2	S	20			10	4.25	0.625	2.076	Y	0	0	0.3
N. Ester	Aug	5	Grabouw	2	S	21			6	3.25		3.025	Y	0	0	3.3
N. Ester	Dec	9	Grabouw	2	S	1			10	3.5	0.25	1.75	Y	0	0	3.7
N. Ester	Dec	9	Grabouw	2	S	2	Dead	U								
N. Ester	Dec	9	Grabouw	2	S	3			10	5.5	1.5	2	Y	0	0	1.4
N. Ester	Dec	9	Grabouw	2	S	4			2	1	0	0.5	Y	0	0	NA
N. Ester	Dec	9	Grabouw	2	S	5	Dead	U								
N. Ester	Dec	9	Grabouw	2	S	6			10	4.416	0.33	2	Y	0	0	3.7
N. Ester	Dec	9	Grabouw	2	S	7			4	1.916	0.25	1.25	Y	0	0	7.1
N. Ester	Dec	9	Grabouw	2	S	8			4	2.166	0.25	1.25	Y	0	0	12.7
N. Ester	Dec	9	Grabouw	2	S	9			10	5.583	0.917	1.25	N	4	0	9.6
N. Ester	Dec	9	Grabouw	2	S	10			2	0.25(LW)	0.5	2.25	N	4	0	2.3
N. Ester	Dec	9	Grabouw	2	S	11			10	4.417	0.58	2	Y	0	0	9
N. Ester	Dec	9	Grabouw	2	S	12			10	4.833	0.75	1.83	Y	0	0	0.5
N. Ester	Dec	9	Grabouw	2	S	13			10	4.417	0.25	2.66	Y	0	0	3.1
N. Ester	Dec	9	Grabouw	2	S	14			10	3.667	0	1.75	Y	0	0	0.9
N. Ester	Dec	9	Grabouw	2	S	15	Dead	U								
N. Ester	Dec	9	Grabouw	2	S	16			7	2.667	0	1.25	Y	0	0	1
N. Ester	Dec	9	Grabouw	2	S	17			10	4.667	1	2.16	Y	0	0	0.6
N. Ester	Dec	9	Grabouw	2	S	19			10	3.417	0.83	1.58	Y	0	0	11.5
N. Ester	Dec	9	Grabouw	2	S	20			10	4.917	3	1	Y	0	0	0.3
N. Ester	Dec	9	Grabouw	2	S	21			10	3.417	1.08	1.75	Y	0	0	1.3

N. Ester	April	13	Grabouw	2	S	1			12	4.75	0.25	1.375	Y	0	3	1.75
N.Ester	April	13	Grabouw	2	S	3			10	3		0.625	Y	0	0	4.67
N.Ester	April	13	Grabouw	2	S	4			11	3.25	1.0125	0.625	Y	0	3	3.56
N.Ester	April	13	Grabouw	2	S	6			9	3.25		1.5	Y	0	0	9.67
N.Ester	April	13	Grabouw	2	S	7	Dead	U								
N.Ester	April	13	Grabouw	2	S	8			9	2.75		1	Y	0	0	1.8
N.Ester	April	13	Grabouw	2	S	9			10	3.25		2.5	Y	0	2	1.8
N.Ester	April	13	Grabouw	2	S	10			4	1.75		0.875	Y	0	0	4
N.Ester	April	13	Grabouw	2	S	11			12	2.5	0.375	2.25	Y	0	0	5.3
N.Ester	April	13	Grabouw	2	S	12			10	4.5		1.125	Y	0	6	3
N.Ester	April	13	Grabouw	2	S	13			9	3.25		1.75	Y	1	0	11.25
N.Ester	April	13	Grabouw	2	S	14	Dead	U								
N.Ester	April	13	Grabouw	2	S	16			10	3.25		1.875	Y	0	0	2.4
N.Ester	April	13	Grabouw	2	S	17			13	2.0825		2.5	Y	0	6	8.67
N.Ester	April	13	Grabouw	2	S	18			12	4.25		1.375	Y	0	0	4.89
N.Ester	April	13	Grabouw	2	S	19			8	2.5	0.375	1.75	Y	0	0	10.3
N.Ester	April	13	Grabouw	2	S	20			10	3.75	0.125	1.25	Y	0	0	5.25
N.Ester	April	13	Grabouw	2	S	21			4	2.25		1.375	Y	4	0	2.72
N. Ester	June	15	Grabouw	2	S	1			10	3	0	0.5	Y	0	0	3
N. Ester	June	15	Grabouw	2	S	3			10	0.75	0	0.25	Y	0	0	4.2
N. Ester	June	15	Grabouw	2	S	4			8	0.25	0	0.75	Y	0	0	16.8
N. Ester	June	15	Grabouw	2	S	6	Dead	U								
N. Ester	June	15	Grabouw	2	S	8			10	1.5	0	1.5	Y	0	0	3
N. Ester	June	15	Grabouw	2	S	9			8	0.75	0	0.125	Y	0	0	4.6
N. Ester	June	15	Grabouw	2	S	10			5	0.25	0	0.125	Y	0	0	10
N. Ester	June	15	Grabouw	2	S	11			10	1.25	0.0625	0.5	Y	0	0	9.6
N. Ester	June	15	Grabouw	2	S	12			12.5	2.5	0	0.25	Y	0	0	8.4
N. Ester	June	15	Grabouw	2	S	13			6	0.75	0	0.5	Y	0	0	4.2
N. Ester	June	15	Grabouw	2	S	16			6	1.5	0	0.5	Y	0	0	1
N. Ester	June	15	Grabouw	2	S	17			10	1.25	0	2	Y	0	0	2
N. Ester	June	15	Grabouw	2	S	18			10	3	0.0625	0.25	Y	0	0	3
N. Ester	June	15	Grabouw	2	S	19			5	0.75	0	0.25	Y	0	0	7
N. Ester	June	15	Grabouw	2	S	20			9	2	0	0.5	Y	0	0	3.75
N. Ester	June	15	Grabouw	2	S	21			4	0.25	0	0.5	Y	0	0	2.8
PPRI	April	0	Elsenburg	1	S	KH11			10.5	3	0	1.5	Y	0	0	1.81
PPRI	April	0	Elsenburg	1	S	KH12			11	2.25	0	0.5	Y	0	0	0.54
PPRI	April	0	Elsenburg	1	S	KH13			7	3	0	0.25	Y	0	0	4
PPRI	April	0	Elsenburg	1	S	KH14			7	3.5	0	0.25	Y	0	0	0
PPRI	April	0	Elsenburg	1	S	KH15			11	2.5	0	0	Y	0	0	0.54
PPRI	April	0	Elsenburg	1	S	KH16			8	3	0	1	Y	0	0	0.54
PPRI	April	0	Elsenburg	1	S	KH17			10.5	3	0	0.25	Y	0	0	0
PPRI	April	0	Elsenburg	1	S	KH18			8	4.5	0	1	Y	0	0	0
PPRI	April	0	Elsenburg	1	S	KH19			10	3	0	0.5	Y	0	0	2.18
PPRI	April	0	Elsenburg	1	S	KH20			10.5	4	0	0.25	Y	0	0	0
PPRI	April	0	Elsenburg	1	S	K1			10	3.5	0.125	0.25	Y	0	0	0.72
PPRI	April	0	Elsenburg	1	S	K2			7	4	0	1.5	Y	0	0	0.18
PPRI	April	0	Elsenburg	1	S	K3			12	3.75	0	3	Y	0	0	0.54
PPRI	April	0	Elsenburg	1	S	K4			10	3	0.25	2.5	Y	0	0	0.18
PPRI	April	0	Elsenburg	1	S	K5			.	3	0.0625	1	Y	0	0	0
PPRI	April	0	Elsenburg	1	S	K6			10	1.75	0	1.5	Y	0	0	0.54
PPRI	April	0	Elsenburg	1	S	K7			8	2.5	0	0.75	Y	0	0	0

PPRI	April	0	Elsenburg	1	S	K8			.	4	0.125	0.25	Y	0	0	0.36
PPRI	April	0	Elsenburg	1	S	K9			10	3	0	1	Y	0	0	1.63
PPRI	April	0	Elsenburg	1	S	K10			12	3	0	1	Y	0	0	0.36
PPRI	June	2	Elsenburg	1	S	KH11			2	0.25	0	0.25	Y	0	0	0
PPRI	June	2	Elsenburg	1	S	KH12			8	2.25	0	0.25	Y	0	0	1.71
PPRI	June	2	Elsenburg	1	S	KH13			3	0	0	1	Y	0	0	0.5
PPRI	June	2	Elsenburg	1	S	KH14			4	1.25	0	1	Y	0	0	6.25
PPRI	June	2	Elsenburg	1	S	KH15			10	5	0	2	Y	0	0	3.42
PPRI	June	2	Elsenburg	1	S	KH16			10	5	0.0625	1	Y	0	0	2.86
PPRI	June	2	Elsenburg	1	S	KH17			13	6.5	0.0625	1	Y	0	0	0
PPRI	June	2	Elsenburg	1	S	KH18			10	5.5	0.25	1.25	Y	0	0	0.49
PPRI	June	2	Elsenburg	1	S	KH19			11	5	1	2	Y	0	0	4.14
PPRI	June	2	Elsenburg	1	S	KH20			12	6	0.25	1.25	Y	0	0	0.47
PPRI	June	2	Elsenburg	1	S	K1			10	5	0.25	2	Y	0	0	0.23
PPRI	June	2	Elsenburg	1	S	K2			6	2.5	0.125	1.5	Y	1	0	2.79
PPRI	June	2	Elsenburg	1	S	K3			10	5	0.125	2	Y	0	0	8.4
PPRI	June	2	Elsenburg	1	S	K4			6	3.5	0.25	2.5	Y	0	0	0.55
PPRI	June	2	Elsenburg	1	S	K5			10	4.5	0.25	1.25	Y	0	0	2
PPRI	June	2	Elsenburg	1	S	K6			10	3.5	0.0625	0.5	Y	0	0	2.14
PPRI	June	2	Elsenburg	1	S	K7			10	5	0.0625	1.5	Y	0	0	0.57
PPRI	June	2	Elsenburg	1	S	K8			11.5	6	0.25	1	Y	1	0	0.23
PPRI	June	2	Elsenburg	1	S	K9			11.75	5	0.125	1.5	Y	0	0	3.08
PPRI	June	2	Elsenburg	1	S	K10			8	4	0.125	1.25	Y	0	0	5.75
PPRI	Sept	5	Elsenburg	1	S	K1			10	3.5	0.125	1.5	Y	0	0	0.3
PPRI	Sept	5	Elsenburg	1	S	K2			6	3	0	2	Y	0	0	1.42
PPRI	Sept	5	Elsenburg	1	S	K3			10	2.5	0	1.5	Y	0	0	5.3
PPRI	Sept	5	Elsenburg	1	S	K4			6	1.5	0	2.5	Y	0	0	0.4
PPRI	Sept	5	Elsenburg	1	S	K5			10	4	0.125	0.5	Y	0	0	5.7
PPRI	Sept	5	Elsenburg	1	S	K6			10	2.5	0.0625	1	Y	0	0	1.5
PPRI	Sept	5	Elsenburg	1	S	K7			10	5	1	0.5	Y	0	0	0.57
PPRI	Sept	5	Elsenburg	1	S	K8			10	2	0	0.25	Y	0	0	2.2
PPRI	Sept	5	Elsenburg	1	S	K9			10	4.5	0.25	0.5	Y	0	0	2.25
PPRI	Sept	5	Elsenburg	1	S	K10			10	4	0.0625	0.5	Y	0	0	3.6
PPRI	Sept	5	Elsenburg	1	S	KH11			1	0.1	0	0.083	Y	0	0	NA
PPRI	Sept	5	Elsenburg	1	S	KH12			5	3	0.1	0.5	Y	0	0	1.09
PPRI	Sept	5	Elsenburg	1	S	KH13	Dead	U								
PPRI	Sept	5	Elsenburg	1	S	KH14			2.5	0.0625	0	.	Y	0	0	.
PPRI	Sept	5	Elsenburg	1	S	KH15			10	5	0.1	0	Y	0	0	5.1
PPRI	Sept	5	Elsenburg	1	S	KH16			8	5	0.1	0.5	Y	0	0	2.6
PPRI	Sept	5	Elsenburg	1	S	KH17			12	6	0.25	1	Y	0	0	2.5
PPRI	Sept	5	Elsenburg	1	S	KH18			7	5.5	0.5	0.5	Y	0	0	0.6
PPRI	Sept	5	Elsenburg	1	S	KH19			8	4	0	1	Y	0	0	1.5
PPRI	Sept	5	Elsenburg	1	S	KH20			10	6	0.14	0.5	Y	0	0	1.6
PPRI	Dec	8	Elsenburg	1	S	K1			11	5	0	3	N	0	7	10
PPRI	Dec	8	Elsenburg	1	S	K2	Dead	V								
PPRI	Dec	8	Elsenburg	1	S	K3			20	6.5	0	0.5	N	0	6.5	27.3
PPRI	Dec	8	Elsenburg	1	S	K4			6	3.125	0	4	N	0	0.5	3.2
PPRI	Dec	8	Elsenburg	1	S	K5			20	5	0.125	0.125	N	0	5	11
PPRI	Dec	8	Elsenburg	1	S	K6			15	4	0	3	N	0	0	11.6
PPRI	Dec	8	Elsenburg	1	S	K7			20	5	0	0.125	N	0	6	13.6
PPRI	Dec	8	Elsenburg	1	S	K8			20	4	0	0.25	N	0	0	3
PPRI	Dec	8	Elsenburg	1	S	K9			16	5.5	0	0.25	N	0	6	16.8

PPRI	Dec	8	Elsenburg	1	S	K10			15	6	0.125	0.25	N	0	7	8.6
PPRI	Dec	8	Elsenburg	1	S	KH11	Dead	U								
PPRI	Dec	8	Elsenburg	1	S	KH12			13	5.5	0	3	N	0	6	5.6
PPRI	Dec	8	Elsenburg	1	S	KH14	Dead	U								
PPRI	Dec	8	Elsenburg	1	S	KH15			10.5	6	0.125	2	N	0	0	5.5
PPRI	Dec	8	Elsenburg	1	S	KH16			6	4	0	1	N	0	0	7.2
PPRI	Dec	8	Elsenburg	1	S	KH17			11	4	0	3	N	0	6	5
PPRI	Dec	8	Elsenburg	1	S	KH18			13	4.5	0.125	3	N	0	6	10.6
PPRI	Dec	8	Elsenburg	1	S	KH19			10.5	4.5	0.25	3	N	0	7	8
PPRI	Dec	8	Elsenburg	1	S	KH20			20	7.5	0.125	1	N	0	6	2
PPRI	Feb	9	Elsenburg	1	S	K1			10	3	0	2	Y	0	0	1.85
PPRI	Feb	9	Elsenburg	1	S	K3			10	1.5	0	1.5	Y	0	0	10.16
PPRI	Feb	9	Elsenburg	1	S	K4			10	1.25	0	2	Y	0	0	0.63
PPRI	Feb	9	Elsenburg	1	S	K5			10	3.5	0.125	1	Y	0	0	2.4
PPRI	Feb	9	Elsenburg	1	S	K6			10	0.75	0	0.25	Y	0	0	5.55
PPRI	Feb	9	Elsenburg	1	S	K7			10	0.75	0	1.25	Y	0	0	0.88
PPRI	Feb	9	Elsenburg	1	S	K8			15	4	0.125	0.75	Y	0	0	2.62
PPRI	Feb	9	Elsenburg	1	S	K9			10	3	0	1	Y	0	0	5.42
PPRI	Feb	9	Elsenburg	1	S	K10	Dead	U								
PPRI	Feb	9	Elsenburg	1	S	KH12			15	1.8125	0	1.1875	Y	0	0	10.32
PPRI	Feb	9	Elsenburg	1	S	KH15			25	0.8125	0	0.125	Y	0	0	7.88
PPRI	Feb	9	Elsenburg	1	S	KH16	Dead	U								
PPRI	Feb	9	Elsenburg	1	S	KH17			20	2	0	0.1875	Y	0	0	7.32
PPRI	Feb	9	Elsenburg	1	S	KH18	Dead	U								
PPRI	Feb	9	Elsenburg	1	S	KH19			20	0.75	0	0.625	N	6	0	13.57
PPRI	Feb	9	Elsenburg	1	S	KH20			25	3	0	1.1875	Y	0	0	1.53
PPRI	March	11	Elsenburg	1	S	K1			8	2.3	0	1.3	Y	0	0	2.8
PPRI	March	11	Elsenburg	1	S	K3			5	2.1	0	1.3	Y	0	0	13.6
PPRI	March	11	Elsenburg	1	S	K4			6	0.8	0	0.6	Y	0	0	4.4
PPRI	March	11	Elsenburg	1	S	K5			6	1.25	0	1.25	Y	0	0	4
PPRI	March	11	Elsenburg	1	S	K6			5	0.25	0	0.125	Y	0	0	9.6
PPRI	March	11	Elsenburg	1	S	K7			6	1.5	0	1.5	Y	0	0	2
PPRI	March	11	Elsenburg	1	S	K8			7	1.375	0	1.325	Y	0	0	3.6
PPRI	March	11	Elsenburg	1	S	K9			6	2.5	0	1.2	Y	0	0	5.6
PPRI	March	11	Elsenburg	1	S	KH12			6	3	0.625	0.8	Y	0	0	14.8
PPRI	March	11	Elsenburg	1	S	KH15			8	0.875	0	1.8	Y	0	0	13.2
PPRI	March	11	Elsenburg	1	S	KH17			6	1.75	0	1	Y	0	0	8
PPRI	March	11	Elsenburg	1	S	KH19			3	1.25	0	0.4	Y	0	0	16
PPRI	March	11	Elsenburg	1	S	KH20			8	3.25	0	1.1	Y	0	0	3.2
PPRI	June	14	Elsenburg	1	S	K1			NA	NA	NA	NA	NA	NA	NA	NA
PPRI	June	14	Elsenburg	1	S	K3			NA	NA	NA	NA	NA	NA	NA	NA
PPRI	June	14	Elsenburg	1	S	K4			NA	NA	NA	NA	NA	NA	NA	NA
PPRI	June	14	Elsenburg	1	S	K5			NA	NA	NA	NA	NA	NA	NA	NA
PPRI	June	14	Elsenburg	1	S	K6			NA	NA	NA	NA	NA	NA	NA	NA
PPRI	June	14	Elsenburg	1	S	K7			NA	NA	NA	NA	NA	NA	NA	NA
PPRI	June	14	Elsenburg	1	S	K8			NA	NA	NA	NA	NA	NA	NA	NA
PPRI	June	14	Elsenburg	1	S	K9			NA	NA	NA	NA	NA	NA	NA	NA
PPRI	June	14	Elsenburg	1	S	KH12			NA	1	0	0	Y	0	0	13.6
PPRI	June	14	Elsenburg	1	S	KH15			NA	2	0	0	Y	0	0	11.6
PPRI	June	14	Elsenburg	1	S	KH17			NA	0.25	0	0	Y	0	0	5.6
PPRI	June	14	Elsenburg	1	S	KH19	Dead	U								
PPRI	June	14	Elsenburg	1	S	KH20			NA	1.5	0	0	Y	0	0	5.2

PPRI	Sept	17	Elsenburg	1	S	K1			18	6.75	0.3125	0.5625	Y	0	0	0
PPRI	Sept	17	Elsenburg	1	S	K3	Dead	U								
PPRI	Sept	17	Elsenburg	1	S	K4	Dead	U								
PPRI	Sept	17	Elsenburg	1	S	K5	Dead	U								
PPRI	Sept	17	Elsenburg	1	S	K6	Dead	U								
PPRI	Sept	17	Elsenburg	1	S	K7			6	2	0	0.5625	Y	0	0	1.09
PPRI	Sept	17	Elsenburg	1	S	K8	Dead	U								
PPRI	Sept	17	Elsenburg	1	S	K9			9	2.625	0	0.5	Y	2	0	2.93
PPRI	Sept	17	Elsenburg	1	S	KH12			3	0.5	0	0.0625	Y	0	0	2.17
PPRI	Sept	17	Elsenburg	1	S	KH15			6	3	0.0625	0.375	Y	0	0	1.43
PPRI	Sept	17	Elsenburg	1	S	KH17			1.5	0	0	0.5625	Y	0	0	8.64
PPRI	Sept	17	Elsenburg	1	S	KH20			5	1	0	0	Y	1	0	7.27
R.Kriebel	May	0	Koelenhof	1	S	V1			6	2	0	1.5	Y	0	0	10.5
R.Kriebel	May	0	Koelenhof	1	S	V2			8	1.5	0	0.5	Y	0	0	10
R.Kriebel	May	0	Koelenhof	1	S	V3			7	2.5	0	2	Y	0	0	6.8
R.Kriebel	May	0	Koelenhof	1	S	V4			6	2	0	1	Y	0	0	13.3
R.Kriebel	May	0	Koelenhof	1	S	V5			6	3.5	0	0	Y	0	0	1.6
R.Kriebel	May	0	Koelenhof	1	S	V6			7	2	0	0.5	Y	0	0	9.5
R.Kriebel	May	0	Koelenhof	1	S	V7			5	2.5	0	0.5	Y	0	0	19.6
R.Kriebel	May	0	Koelenhof	1	S	V8			6	3	0	1	Y	0	0	23
R.Kriebel	May	0	Koelenhof	1	S	V9			5	3	0	1	Y	0	0	23.6
R.Kriebel	May	0	Koelenhof	1	S	V10			6	.	0	0.5	Y	0	0	20.5
R.Kriebel	May	0	Koelenhof	1	S	V11			5	0.5	0	0.25	Y	0	0	8
R.Kriebel	May	0	Koelenhof	1	S	V12			5	1.5	0	0.25	Y	0	0	14.5
R.Kriebel	May	0	Koelenhof	1	S	V13			7	1.5	0	0.5	Y	0	0	11.5
R.Kriebel	May	0	Koelenhof	1	S	V14			5	2.5	0	0.25	Y	0	0	8.6
R.Kriebel	May	0	Koelenhof	1	S	V15			6	1.5	0	0.5	Y	0	0	10.8
R.Kriebel	May	0	Koelenhof	1	S	V16			6	2	0	0.5	Y	0	0	12
R.Kriebel	May	0	Koelenhof	1	S	V17			5	0.5	0	0.25	Y	0	0	9.5
R.Kriebel	May	0	Koelenhof	1	S	V18			5	0.25	0	0	Y	0	0	19
R.Kriebel	May	0	Koelenhof	1	S	V19			5	1.5	0	0.5	Y	0	0	7
R.Kriebel	May	0	Koelenhof	1	S	V20			7	2	0	1	Y	0	0	19.2
R.Kriebel	July	2	Koelenhof	1	S	V1			5	2.5	0	0.0625	Y	0	0	2
R.Kriebel	July	2	Koelenhof	1	S	V2			4	1.5	0	0.5	Y	0	0	6.3
R.Kriebel	July	2	Koelenhof	1	S	V3			7	4	0	0.125	Y	0	0	7
R.Kriebel	July	2	Koelenhof	1	S	V4			4	2	0	0.5	Y	0	0	6.5
R.Kriebel	July	2	Koelenhof	1	S	V5			12	5	0	0.0625	Y	0	0	4.8
R.Kriebel	July	2	Koelenhof	1	S	V6			12	4	0	0.4375	Y	0	0	3.6
R.Kriebel	July	2	Koelenhof	1	S	V7			12.5	4.5	0.125	0.125	Y	0	0	1.6
R.Kriebel	July	2	Koelenhof	1	S	V8			8	2	0	0.25	Y	0	0	2.2
R.Kriebel	July	2	Koelenhof	1	S	V9			11.5	4.5	0.0625	0	Y	0	0	4.5
R.Kriebel	July	2	Koelenhof	1	S	V10			8	4	0.0625	0.4375	Y	0	0	1.8
R.Kriebel	July	2	Koelenhof	1	S	V11			8	4.25	0	0.1875	Y	0	0	4.2
R.Kriebel	July	2	Koelenhof	1	S	V12			8	3.75	0	0.75	Y	0	0	6.9
R.Kriebel	July	2	Koelenhof	1	S	V13			12	3.5625	0	0.5	Y	0	0	2
R.Kriebel	July	2	Koelenhof	1	S	V14			11	4.5	0	1.25	Y	0	0	2.1
R.Kriebel	July	2	Koelenhof	1	S	V15			8	3.5	0	1.0625	Y	0	0	3.2
R.Kriebel	July	2	Koelenhof	1	S	V16			8	3	0.0625	0.875	Y	0	0	6
R.Kriebel	July	2	Koelenhof	1	S	V17			8	3	0.125	0.75	Y	0	0	2.6
R.Kriebel	July	2	Koelenhof	1	S	V18			7	2.5	0	0.3125	Y	0	0	3.4
R.Kriebel	July	2	Koelenhof	1	S	V19			12.5	4.5625	0.0625	0.6875	Y	0	0	3.8

R.Kriebel	July	2	Koelenhof	1	S	V20			7	2.75	0.0625	0.375	Y	0	0	4.6
R.Kriebel	Sept	4	Koelenhof	1	S	V1			7	4.25	0.1875	0.4375	Y	0	0	0.75
R.Kriebel	Sept	4	Koelenhof	1	S	V2			3	1.25	0.25	0.125	Y	0	0	2.28
R.Kriebel	Sept	4	Koelenhof	1	S	V3			10	5.5	0.75	0.325	Y	0	0	4
R.Kriebel	Sept	4	Koelenhof	1	S	V4			5	2	0	0.25	Y	0	0	1
R.Kriebel	Sept	4	Koelenhof	1	S	V5			10	5.75	0	0.375	Y	0	0	2.33
R.Kriebel	Sept	4	Koelenhof	1	S	V6			10	5.75	0.1875	0.5625	Y	0	0	2.5
R.Kriebel	Sept	4	Koelenhof	1	S	V7			10	7	0.125	0.3125	Y	0	0	6.5
R.Kriebel	Sept	4	Koelenhof	1	S	V8			8	1.875	0.5	0.3125	Y	0	0	2.85
R.Kriebel	Sept	4	Koelenhof	1	S	V9			10	5.25	0.625	0.375	Y	0	0	3.5
R.Kriebel	Sept	4	Koelenhof	1	S	V10			10	5.25	0.625	0.9375	Y	0	0	2.28
R.Kriebel	Sept	4	Koelenhof	1	S	V11			7	3.75	0.1875	0.3125	Y	0	0	5.33
R.Kriebel	Sept	4	Koelenhof	1	S	V12			7	4.25	0	0.4375	Y	0	0	6
R.Kriebel	Sept	4	Koelenhof	1	S	V13			10	6.5	0.1875	0.375	Y	0	0	5.75
R.Kriebel	Sept	4	Koelenhof	1	S	V14			10	6	0.3125	0.5	Y	0	0	1.33
R.Kriebel	Sept	4	Koelenhof	1	S	V15			10	7	0.4375	0.75	Y	0	0	5
R.Kriebel	Sept	4	Koelenhof	1	S	V16			10	4.125	1.0625	0.4375	Y	0	0	2.57
R.Kriebel	Sept	4	Koelenhof	1	S	V17			10	2.625	0.875	0.375	Y	0	0	5.75
R.Kriebel	Sept	4	Koelenhof	1	S	V18			10	3.625	0.5625	0.75	Y	0	0	1.33
R.Kriebel	Sept	4	Koelenhof	1	S	V19			12.5	5.625	0.625	0.4375	Y	0	0	5.55
R.Kriebel	Sept	4	Koelenhof	1	S	V20			11.5	3.25	0.6875	0.375	Y	0	0	5
R.Kriebel	Dec	7	Koelenhof	1	S	V1			11	5.5	0	1.5	Y	0	9	1.3
R.Kriebel	Dec	7	Koelenhof	1	S	V2			6	3	0.125	1	Y	0	0	4
R.Kriebel	Dec	7	Koelenhof	1	S	V3			11	7.5	0.25	0.125	Y	0	7	2.2
R.Kriebel	Dec	7	Koelenhof	1	S	V4			10	7	0.25	0.5	Y	0	3.5	0.8
R.Kriebel	Dec	7	Koelenhof	1	S	V5			10	3	0	3	Y	2	4	4.8
R.Kriebel	Dec	7	Koelenhof	1	S	V6			11	4.5	0.125	0.5	Y	0	9	10
R.Kriebel	Dec	7	Koelenhof	1	S	V7			11	4.5	0	0.5	Y	0	9	18.4
R.Kriebel	Dec	7	Koelenhof	1	S	V8			1	0	0	0	N	0	0	NA
R.Kriebel	Dec	7	Koelenhof	1	S	V9			11	4	0	2	Y	0	9	8.2
R.Kriebel	Dec	7	Koelenhof	1	S	V10			11	5.25	0.25	2.5	Y	0	9	4.5
R.Kriebel	Dec	7	Koelenhof	1	S	V11			10	4	0	2	Y	0	0	4
R.Kriebel	Dec	7	Koelenhof	1	S	V12			10	5.5	0	1.5	Y	0	0	5
R.Kriebel	Dec	7	Koelenhof	1	S	V13			11	5	0.25	3.5	Y	0	9	13
R.Kriebel	Dec	7	Koelenhof	1	S	V14			11	3	0	3.5	Y	0	4	7.5
R.Kriebel	Dec	7	Koelenhof	1	S	V15			11	6	0.25	3.5	Y	0	7.5	12.5
R.Kriebel	Dec	7	Koelenhof	1	S	V16			11	5.5	0.125	3	Y	0	9	9.5
R.Kriebel	Dec	7	Koelenhof	1	S	V17			11	8	0.5	3	Y	0	6.5	9.6
R.Kriebel	Dec	7	Koelenhof	1	S	V18			10.5	5.5	0.25	2	Y	0	4.5	7
R.Kriebel	Dec	7	Koelenhof	1	S	V19			11.25	5	0.125	1.5	Y	0	13.5	6.5
R.Kriebel	Dec	7	Koelenhof	1	S	V20			10.5	4	0.125	3	Y	0	4.5	8.5
R.Kriebel	Feb	8	Koelenhof	1	S	V1			20	2.5	0	0.25	Y	0	0	1.78
R.Kriebel	Feb	8	Koelenhof	1	S	V2			10	1.5	0	0.125	Y	0	0	1.07
R.Kriebel	Feb	8	Koelenhof	1	S	V3			15	2.5	0.125	0.0625	Y	0	0	8.57
R.Kriebel	Feb	8	Koelenhof	1	S	V4			20	3.5	0.125	0.125	Y	0	0	4.05
R.Kriebel	Feb	8	Koelenhof	1	S	V5			15	3	0	1.5	Y	0	0	2.4
R.Kriebel	Feb	8	Koelenhof	1	S	V6			15	2.5	0	0.125	Y	0	0	2.94
R.Kriebel	Feb	8	Koelenhof	1	S	V7			20	3.5	0	0.25	Y	0	0	3.84
R.Kriebel	Feb	8	Koelenhof	1	S	V8	Dead	U								
R.Kriebel	Feb	8	Koelenhof	1	S	V9			15	2.75	0	0.25	Y	0	0	5.38
R.Kriebel	Feb	8	Koelenhof	1	S	V10			15	3.5	0	1.75	Y	0	0	4.44
R.Kriebel	Feb	8	Koelenhof	1	S	V11			20	4.75	0	0.5	Y	0	0	2.27

R.Kriebel	Feb	8	Koelenhof	1	S	V12			15	2.5	0	0.75	Y	0	0	1.21
R.Kriebel	Feb	8	Koelenhof	1	S	V13			20	3.25	0	1	Y	0	0	6.2
R.Kriebel	Feb	8	Koelenhof	1	S	V14			15	3	0	1.5	Y	0	0	2.08
R.Kriebel	Feb	8	Koelenhof	1	S	V15			20	3.5	0	1.25	Y	0	0	5.9
R.Kriebel	Feb	8	Koelenhof	1	S	V16			20	2.125	0	1.5	Y	0	0	3.37
R.Kriebel	Feb	8	Koelenhof	1	S	V17			20	2.5	0	0.125	Y	0	0	6.28
R.Kriebel	Feb	8	Koelenhof	1	S	V18			20	3	0	1	Y	0	0	4.4
R.Kriebel	Feb	8	Koelenhof	1	S	V19			20	1.25	0	0.125	Y	0	0	3.29
R.Kriebel	Feb	8	Koelenhof	1	S	V20			15	0.75	0	0.25	Y	0	0	5.71
R.Kriebel	March	9	Koelenhof	1	S	V1			4	0.25	0	0.5	Y	0	5.6	NA
R.Kriebel	March	9	Koelenhof	1	S	V2			4	0.875	0	0.4375	Y	0	10.8	NA
R.Kriebel	March	9	Koelenhof	1	S	V3			3	1	0	0.25	Y	0	10	NA
R.Kriebel	March	9	Koelenhof	1	S	V4			4	2	0	0.1875	Y	0	16	NA
R.Kriebel	March	9	Koelenhof	1	S	V5			5	1	0	0.375	Y	0	13.2	NA
R.Kriebel	March	9	Koelenhof	1	S	V6			4	1.5	0	0.25	Y	0	18.8	NA
R.Kriebel	March	9	Koelenhof	1	S	V7			4	0.075	0	0.1875	Y	0	14.8	NA
R.Kriebel	March	9	Koelenhof	1	S	V9	Dead	U								
R.Kriebel	March	9	Koelenhof	1	S	V10			3	1.75	0	0.5625	Y	0	12.8	NA
R.Kriebel	March	9	Koelenhof	1	S	V11			4	1	0	0.5	Y	0	17.6	NA
R.Kriebel	March	9	Koelenhof	1	S	V12	Dead	U								
R.Kriebel	March	9	Koelenhof	1	S	V13			4	1.25	0	0.5	Y	0	8.4	NA
R.Kriebel	March	9	Koelenhof	1	S	V14			4	1	0	0.625	Y	0	11.2	NA
R.Kriebel	March	9	Koelenhof	1	S	V15			4	0.375	0	1.25	Y	0	15.6	NA
R.Kriebel	March	9	Koelenhof	1	S	V16			4	1	0	0.4375	Y	0	8.8	NA
R.Kriebel	March	9	Koelenhof	1	S	V17			NA	0.375	0	0.1875	Y	0	20	NA
R.Kriebel	March	9	Koelenhof	1	S	V18			3	0.25	0	0.125	Y	0	13.6	NA
R.Kriebel	March	9	Koelenhof	1	S	V19			4	1	0	0.1875	Y	0	6.4	NA
R.Kriebel	March	9	Koelenhof	1	S	V20			3	0.25	0	0.1875	Y	0	14	NA
R.Kriebel	June	13	Koelenhof	1	S	V1			7	1.125	0	0.25	Y	0	0	7
R.Kriebel	June	13	Koelenhof	1	S	V2			4	0.5	0	0.3125	Y	0	0	8.25
R.Kriebel	June	13	Koelenhof	1	S	V3			3	NA	0	0.0625	Y	0	0	17
R.Kriebel	June	13	Koelenhof	1	S	V4			6	0.75	0	0.125	Y	0	0	3.5
R.Kriebel	June	13	Koelenhof	1	S	V5			7	1.25	0	0.375	Y	0	0	15.5
R.Kriebel	June	13	Koelenhof	1	S	V6			NA	0.75	0	0.3125	Y	0	0	10.75
R.Kriebel	June	13	Koelenhof	1	S	V7			5	0.375	0	0.0625	Y	0	0	19.2
R.Kriebel	June	13	Koelenhof	1	S	V10			6	1	0	0.25	Y	0	0	8
R.Kriebel	June	13	Koelenhof	1	S	V11			6	1	0	0.5625	Y	0	0	14.25
R.Kriebel	June	13	Koelenhof	1	S	V13			5	0.1875	0	0.1875	Y	0	0	12.25
R.Kriebel	June	13	Koelenhof	1	S	V14			6	0.625	0	0.875	Y	0	0	16.4
R.Kriebel	June	13	Koelenhof	1	S	V15			5	0.625	0	0.4375	Y	0	0	17.25
R.Kriebel	June	13	Koelenhof	1	S	V16			5	0.5	0	0.125	Y	0	0	17
R.Kriebel	June	13	Koelenhof	1	S	V17	Dead	U								
R.Kriebel	June	13	Koelenhof	1	S	V18			3	0.0625	0	0	Y	0	0	8
R.Kriebel	June	13	Koelenhof	1	S	V19			6	1.25	0	0.125	Y	0	0	7.67
R.Kriebel	June	13	Koelenhof	1	S	V20	Dead	U								
R.Kriebel	Sept	16	Koelenhof	1	S	V1			3	0.5	0	0.75	Y	0	0	5.63
R.Kriebel	Sept	16	Koelenhof	1	S	V2			5	1.75	0	0.3125	Y	3	0	2.08
R.Kriebel	Sept	16	Koelenhof	1	S	V3			3	1.5	0	0.125	Y	0	0	5.77
R.Kriebel	Sept	16	Koelenhof	1	S	V4			7	3.75	0.1875	0.25	Y	0	0	0.68
R.Kriebel	Sept	16	Koelenhof	1	S	V5			11.5	5.75	0.125	0.375	Y	0	0	4.36
R.Kriebel	Sept	16	Koelenhof	1	S	V6			4	1	0	0	N	1	0	5.64
R.Kriebel	Sept	16	Koelenhof	1	S	V7	Dead	U								

R.Kriebel	Sept	16	Koelenhof	1	S	V10			5	2.25	0.125	0.125	Y	1	0	5.83
R.Kriebel	Sept	16	Koelenhof	1	S	V11			.	2.75	0	0.375	Y	0	0	1.67
R.Kriebel	Sept	16	Koelenhof	1	S	V13			4	1.375	0	0.1875	Y	0	0	5.2
R.Kriebel	Sept	16	Koelenhof	1	S	V14			5	2	0	0.3125	Y	0	0	8.42
R.Kriebel	Sept	16	Koelenhof	1	S	V15			8	3.5	0.1875	0.1875	Y	0	0	7.44
R.Kriebel	Sept	16	Koelenhof	1	S	V16			5	2	0	0	Y	0	0	4.04
R.Kriebel	Sept	16	Koelenhof	1	S	V18	Dead	U								
R.Kriebel	Sept	16	Koelenhof	1	S	V19			8	4.25	0.125	0	Y	0	0	0.78
Linington	May	0	Wolseley	1	S	A1			11	1	0.125	1.25	Y	0	0	1.5
Linington	May	0	Wolseley	1	S	A2			10	1.5	0	0.625	Y	0	0	0
Linington	May	0	Wolseley	1	S	A3			6	0.5	0	0.5	Y	0	0	0.5
Linington	May	0	Wolseley	1	S	A4			9	0.75	0	0.875	Y	0	0	0.5
Linington	May	0	Wolseley	1	S	A5			11.5	1.375	0	1.25	Y	0	0	1.5
Linington	May	0	Wolseley	1	S	A6			12.5	1.25	0	1.375	Y	0	0	1
Linington	May	0	Wolseley	1	S	A7			14	1.5	0	2.625	Y	0	0	1
Linington	May	0	Wolseley	1	S	A8			13.5	1.625	0	2.5	Y	0	0	1.5
Linington	May	0	Wolseley	1	S	A9			12	1.5	0	2.375	Y	0	0	7.5
Linington	May	0	Wolseley	1	S	A10			9.5	0.375	0	1.625	Y	0	0	1
Linington	May	0	Wolseley	1	S	B1			10.5	1.75	0	2.875	Y	0	0	2.4
Linington	May	0	Wolseley	1	S	B2			8	2	0	1.3125	Y	0	0	13.5
Linington	May	0	Wolseley	1	S	B3			10.5	2.25	0	1.125	Y	0	0	5
Linington	May	0	Wolseley	1	S	B4			7.5	1	0	0.625	Y	0	0	4
Linington	May	0	Wolseley	1	S	B5			13.5	2.5	0	3.25	Y	0	0	3.5
Linington	May	0	Wolseley	1	S	B6			12	4	0	2.125	Y	0	0	1.1
Linington	May	0	Wolseley	1	S	B7			7.5	2.75	0	0.75	Y	0	0	6.5
Linington	May	0	Wolseley	1	S	B8			12.5	3.25	0.125	1.625	Y	0	0	4.8
Linington	May	0	Wolseley	1	S	B9			7.5	1.75	0	2.5	Y	0	0	19
Linington	May	0	Wolseley	1	S	B10			10	2.25	0	2.5	Y	0	0	10
Linington	May	0	Wolseley	1	S	C1			11.5	2.125	0	2.125	Y	0	0	3.6
Linington	May	0	Wolseley	1	S	C2			7.5	1	0	1	Y	0	0	3
Linington	May	0	Wolseley	1	S	C3			6.5	1.75	0	1	Y	0	0	6.4
Linington	May	0	Wolseley	1	S	C4			14.5	3.25	0.5	1.875	Y	0	0	3.2
Linington	May	0	Wolseley	1	S	C5			6.5	1.75	0.125	0.875	Y	0	0	6.5
Linington	May	0	Wolseley	1	S	C6			14.5	3.5	0	1.5	Y	0	0	0
Linington	May	0	Wolseley	1	S	C7			5.5	3.5	0	1.5	Y	0	0	0.5
Linington	May	0	Wolseley	1	S	C8			13	2	0	1.125	Y	0	0	1.5
Linington	May	0	Wolseley	1	S	C9			9.5	3.75	0	1.125	Y	0	0	1
Linington	May	0	Wolseley	1	S	C10			11.5	3	0	1.125	Y	0	0	1
Linington	Nov	6	Wolseley	1	2H, 1P	A1			5	2.625	0	2.625	Y	0	0	8.5
Linington	Nov	6	Wolseley	1	2H, 1P	A2			9	3.5	0	1.4375	Y	0	0	7.7
Linington	Nov	6	Wolseley	1	2H, 1P	A3			5	2.8125	0	0.4375	Y	0	0	7
Linington	Nov	6	Wolseley	1	2H, 1P	A4			5	3.75	0.125	0.75	Y	0	0	8.3
Linington	Nov	6	Wolseley	1	2H, 1P	A5			8	3.1875	0.0625	1.1875	Y	0	0	11.3
Linington	Nov	6	Wolseley	1	2H, 1P	A6			3	3.25	0	0.625	Y	2	0	7.1
Linington	Nov	6	Wolseley	1	2H, 1P	A7			4	1.75	0	3.875	Y	0	0	.
Linington	Nov	6	Wolseley	1	2H, 1P	A8			6	2	0	2.0625	Y	0	0	6.3
Linington	Nov	6	Wolseley	1	2H, 1P	A9			4	1.5	0	2.375	Y	9	0	.
Linington	Nov	6	Wolseley	1	2H, 1P	A10			5	2.375	0.0625	2.4375	Y	0	0	9.5
Linington	Nov	6	Wolseley	1	2H, 1P	B1			11	3.25	0	3.625	Y	2	0	9.2
Linington	Nov	6	Wolseley	1	2H, 1P	B2			5	2.25	0	1.5	Y	0	0	9.8
Linington	Nov	6	Wolseley	1	2H, 1P	B3			10	2	0.125	0.25	Y	0	0	10.9

Linington	Nov	6	Wolseley	1	2H, 1P	B4			7	2.5	0.5	1.375	Y	0	0	3.9
Linington	Nov	6	Wolseley	1	2H, 1P	B5	Dead	U								
Linington	Nov	6	Wolseley	1	2H, 1P	B6			8	4.375	0.1875	0.25	Y	0	0	2
Linington	Nov	6	Wolseley	1	2H, 1P	B7	Dead	U								
Linington	Nov	6	Wolseley	1	2H, 1P	B8			8	4.125	0	1	Y	0	0	13
Linington	Nov	6	Wolseley	1	2H, 1P	B9			8.5	2.5	0	3.375	Y	4	0	14
Linington	Nov	6	Wolseley	1	2H, 1P	B10			8	5.5	0	0.75	Y	0	0	6.4
Linington	Nov	6	Wolseley	1	2H, 1P	C1			7	2.0625	0.0625	1.625	Y	2	0	7.7
Linington	Nov	6	Wolseley	1	2H, 1P	C2			5	0.375	0	1.125	Y	2	0	3.6
Linington	Nov	6	Wolseley	1	2H, 1P	C3			3	0	0	1.3125	Y	1	0	.
Linington	Nov	6	Wolseley	1	2H, 1P	C4	Dead	U								
Linington	Nov	6	Wolseley	1	2H, 1P	C5			8	3.0625	0	1.375	Y	0	0	15.6
Linington	Nov	6	Wolseley	1	2H, 1P	C6			11.5	0.125	0	0.625	Y	4	0	16.6
Linington	Nov	6	Wolseley	1	2H, 1P	C7	Dead	U								
Linington	Nov	6	Wolseley	1	2H, 1P	C8			2	1.75	0	0.25	Y	0	0	1.4
Linington	Nov	6	Wolseley	1	2H, 1P	C9			6	3.125	0.125	1.75	Y	0	0	15.7
Linington	Nov	6	Wolseley	1	2H, 1P	C10			7	0.875	0.125	2.3125	Y	2	0	4.8
Linington	Jan	8	Wolseley	1	S	A1			11	2.25	0.25	0.3125	Y	0	0	0
Linington	Jan	8	Wolseley	1	S	A2			11.5	3.25	0	1.5	Y	0	5	2.8
Linington	Jan	8	Wolseley	1	S	A3			14	2.125	0	0.0625	Y	0	5	3
Linington	Jan	8	Wolseley	1	S	A4			14.5	2.0625	0	0.0625	Y	0	0	5.5
Linington	Jan	8	Wolseley	1	S	A5			8	2.125	0	1.25	Y	0	0	4
Linington	Jan	8	Wolseley	1	S	A6			11	2	0	0.875	Y	0	0	1.5
Linington	Jan	8	Wolseley	1	S	A7			11.5	2.25	0.0625	0.0625	Y	0	5	0.5
Linington	Jan	8	Wolseley	1	S	A8			9	1.3125	0	0.6875	Y	0	0	2
Linington	Jan	8	Wolseley	1	S	A9			5	1.3125	0	0.5625	Y	0	0	0
Linington	Jan	8	Wolseley	1	S	A10			8.5	1.5625	0	1.25	Y	0	5	0
Linington	Jan	8	Wolseley	1	S	B1			12	3.375	0	2.25	Y	0	5	1.6
Linington	Jan	8	Wolseley	1	S	B2			15	3.0625	0.125	0.5	Y	0	5	2
Linington	Jan	8	Wolseley	1	S	B3			5	1.8125	0	0.5	Y	0	5	1
Linington	Jan	8	Wolseley	1	S	B4			9	2	0.0625	0.5	Y	0	5	1.5
Linington	Jan	8	Wolseley	1	S	B6			6.5	3.5	0	0.75	Y	0	0	0.5
Linington	Jan	8	Wolseley	1	S	B8			12	3	0	0.8125	Y	0	10	5.6
Linington	Jan	8	Wolseley	1	S	B9			12	3.5625	0	0.5	Y	0	10	3.2
Linington	Jan	8	Wolseley	1	S	B10			12.5	2.75	0	0.1875	Y	0	10	6
Linington	Jan	8	Wolseley	1	S	C1			8	3.25	0	0.5	Y	0	0	1
Linington	Jan	8	Wolseley	1	S	C2			12	1.8125	0	1.3125	Y	0	0	NA
Linington	Jan	8	Wolseley	1	S	C3			3	1.5625	0	0.5625	Y	0	0	NA
Linington	Jan	8	Wolseley	1	S	C5			8	0.8125	0	0.1875	Y	0	0	7.5
Linington	Jan	8	Wolseley	1	S	C6			13	2.8125	0.0625	0.3125	Y	0	5	2.8
Linington	Jan	8	Wolseley	1	S	C8			4	1.5	0	0.0625	Y	0	0	2.5
Linington	Jan	8	Wolseley	1	S	C9			10	2.25	0.0625	0.6875	Y	0	5	3
Linington	Jan	8	Wolseley	1	S	C10			12.5	2.625	0.0625	0.25	Y	0	5	1
G.van Zyl	Feb	0	Malmesbury	1	S	1			17.5	1.25	0	0.125	Y	0	16	0.8
G.van Zyl	Feb	0	Malmesbury	1	S	2			15	2	0	0.25	Y	0	3	4.8
G.van Zyl	Feb	0	Malmesbury	1	S	3			20	1.75	0	0.25	Y	1	4	1.2
G.van Zyl	Feb	0	Malmesbury	1	S	4			20	0.5	0	0.25	Y	0	20	4.2
G.van Zyl	Feb	0	Malmesbury	1	S	5			12	1	0	0.25	Y	0	9	1.4
G.van Zyl	Feb	0	Malmesbury	1	S	6			15	2	0	0.25	Y	0	12	1
G.van Zyl	Feb	0	Malmesbury	1	S	7			10	1.25	0	0.25	Y	0	5	0.4
G.van Zyl	Feb	0	Malmesbury	1	S	8			15	1.5	0	0.125	Y	0	8	1

G.van Zyl	Feb	0	Malmesbury	1	S	9			20	1.25	0	0.125	Y	0	17	0.6
G.van Zyl	Feb	0	Malmesbury	1	S	10			15	1	0	0	Y	0	6	8.4
G.van Zyl	Feb	0	Malmesbury	1	S	11			20	0.25	0	0	Y	0	17	3.6
G.van Zyl	Feb	0	Malmesbury	1	S	12			12.5	1	0	0.125	Y	0	5	3.2
G.van Zyl	Feb	0	Malmesbury	1	S	13			13.5	1	0	0.125	Y	0	5	2
G.van Zyl	Feb	0	Malmesbury	1	S	14			12	1	0	0.125	Y	0	6	4.4
G.van Zyl	Feb	0	Malmesbury	1	S	15			15	1	0	0	Y	0	10	3.4
G.van Zyl	Feb	0	Malmesbury	1	S	16			10	0.25	0	0	Y	0	0	0.8
G.van Zyl	Feb	0	Malmesbury	1	S	17			10	0.5	0	0	Y	0	4	6.4
G.van Zyl	Feb	0	Malmesbury	1	S	18			17.5	1.75	0.125	0.125	Y	0	10	1.4
G.van Zyl	Feb	0	Malmesbury	1	S	19			10	0.5	0	0	Y	0	0	0.2
G.van Zyl	Feb	0	Malmesbury	1	S	20			11	0	0	0	Y	0	0	6.8
G.van Zyl	May	3	Malmesbury	1	S	1			11.5	0.75	0	0	Y	0	3	4.4
G.van Zyl	May	3	Malmesbury	1	S	2			11.5	0.25	0	0	Y	0	2	13.5
G.van Zyl	May	3	Malmesbury	1	S	3			12	0.25	0	0	Y	0	3	9.5
G.van Zyl	May	3	Malmesbury	1	S	4			12	0.25	0	0	Y	0	0	7.3
G.van Zyl	May	3	Malmesbury	1	S	5			11	0.5	0	0	Y	0	0	10
G.van Zyl	May	3	Malmesbury	1	S	6			8	0.5	0	0	Y	0	0	3.3
G.van Zyl	May	3	Malmesbury	1	S	7			8	0.5	0	0	Y	0	0	8
G.van Zyl	May	3	Malmesbury	1	S	8			5	0.25	0	0	Y	0	0	3.3
G.van Zyl	May	3	Malmesbury	1	S	9			12.5	1	0	0	Y	0	2	4.6
G.van Zyl	May	3	Malmesbury	1	S	10	Dead	U								
G.van Zyl	May	3	Malmesbury	1	S	11			5	0.25	0	0	Y	0	0	10
G.van Zyl	May	3	Malmesbury	1	S	12			4	0.25	0	0	Y	0	0	21
G.van Zyl	May	3	Malmesbury	1	S	13			6	0.25	0	0	Y	0	0	4
G.van Zyl	May	3	Malmesbury	1	S	14			4	0.25	0	0	Y	0	0	10
G.van Zyl	May	3	Malmesbury	1	S	15			6	0.25	0	0	Y	0	0	14.6
G.van Zyl	May	3	Malmesbury	1	S	16	Dead	U								
G.van Zyl	May	3	Malmesbury	1	S	17			8	0.5	0	0	Y	0	0	15.3
G.van Zyl	May	3	Malmesbury	1	S	18			12.5	0.5	0	0	Y	0	0	4.6
G.van Zyl	May	3	Malmesbury	1	S	19			4	0.25	0	0	Y	0	0	4
G.van Zyl	May	3	Malmesbury	1	S	20			11.5	0.25	0	0	Y	0	0	16.5
G.van Zyl	Oct	8	Malmesbury	1	1P	1			9	4	0.5	2	Y	0	0	23.8
G.van Zyl	Oct	8	Malmesbury	1	1P	2			5.5	0.5	0	2	Y	1	0	9.26
G.van Zyl	Oct	8	Malmesbury	1	1P	3	Lost									
G.van Zyl	Oct	8	Malmesbury	1	1P	4	Dead	U								
G.van Zyl	Oct	8	Malmesbury	1	1P	5			7.5	1.5	0.25	0.5	Y	1	0	NA
G.van Zyl	Oct	8	Malmesbury	1	1P	6	Lost									
G.van Zyl	Oct	8	Malmesbury	1	1P	7			12.5	7	0.5	2	Y	0	10	7.49
G.van Zyl	Oct	8	Malmesbury	1	1P	8			12.5	5	0.5	2	Y	0	0	7.55
G.van Zyl	Oct	8	Malmesbury	1	1P	9	Lost									
G.van Zyl	Oct	8	Malmesbury	1	1P	11	Lost									
G.van Zyl	Oct	8	Malmesbury	1	1P	12	Lost									
G.van Zyl	Oct	8	Malmesbury	1	1P	13			15	7	0.5	1	Y	1	0	4.31
G.van Zyl	Oct	8	Malmesbury	1	1P	14			13.5	7	0.5	2	Y	0	0	7.13
G.van Zyl	Oct	8	Malmesbury	1	1P	15			6	1.5	0.25	1	Y	0	0	1.68
G.van Zyl	Oct	8	Malmesbury	1	1P	17	Lost									
G.van Zyl	Oct	8	Malmesbury	1	1P	18			6	2	0.25	1	Y	0	0	5.45
G.van Zyl	Oct	8	Malmesbury	1	1P	19	Lost									
G.van Zyl	Oct	8	Malmesbury	1	1P	20			15	7	0.5	1	Y	0	10	5.34
G.van Zyl	Jan	10	Malmesbury	1	S	1			5	2.5	0	0.25	Y	1	0	3.18
G.van Zyl	Jan	10	Malmesbury	1	S	2			4	1.5	0	0.75	Y	0	0	4.8

G.van Zyl	Jan	10	Malmesbury	1	S	3			9.5	3.5	0.25	1.25	Y	0	5	1.45
G.van Zyl	Jan	10	Malmesbury	1	S	5			4	1.5	0	0.5	Y	0	0	1.94
G.van Zyl	Jan	10	Malmesbury	1	S	6			5	0.5	0	3	Y	2	4	8.92
G.van Zyl	Jan	10	Malmesbury	1	S	7			12	2	0	0.5	Y	0	2	6.71
G.van Zyl	Jan	10	Malmesbury	1	S	8			3.5	0.25	0	1	Y	8	0	3.79
G.van Zyl	Jan	10	Malmesbury	1	S	9			6	0.25	0	0.25	Y	0	0	3.67
G.van Zyl	Jan	10	Malmesbury	1	S	11	Lost									
G.van Zyl	Jan	10	Malmesbury	1	S	12			12.5	4	0.25	1.5	Y	0	0	0.85
G.van Zyl	Jan	10	Malmesbury	1	S	13			8.5	2	0	0.5	Y	0	5	5.75
G.van Zyl	Jan	10	Malmesbury	1	S	14			12	3.5	0.125	0.75	Y	0	5	6.92
G.van Zyl	Jan	10	Malmesbury	1	S	15			0.75	0.25	0	0.25	Y	0	5	NA
G.van Zyl	Jan	10	Malmesbury	1	S	17	Lost									
G.van Zyl	Jan	10	Malmesbury	1	S	18			8.5	2	0	1	Y	0	3	4.79
G.van Zyl	Jan	10	Malmesbury	1	S	19			8.5	2.25	0.125	0.5	Y	0	3	1.15
G.van Zyl	Jan	10	Malmesbury	1	S	20			8.5	2.5	0.125	1.5	Y	0	5	10.43
G.van Zyl	July	16	Malmesbury	1	S	1			2	0.5	0	0.25	NA	0	0	2
G.van Zyl	July	16	Malmesbury	1	S	2			4	1	0	0.25	NA	0	0	14
G.van Zyl	July	16	Malmesbury	1	S	3	Dead	V								
G.van Zyl	July	16	Malmesbury	1	S	5			1	0.125	0	0	NA	0	0	22
G.van Zyl	July	16	Malmesbury	1	S	6	Dead	U								
G.van Zyl	July	16	Malmesbury	1	S	7			3	0.5	0	0.25	NA	0	0	9
G.van Zyl	July	16	Malmesbury	1	S	8	Dead	U								
G.van Zyl	July	16	Malmesbury	1	S	9			2	0.5	0	0	NA	0	0	14
G.van Zyl	July	16	Malmesbury	1	S	11	Lost									
G.van Zyl	July	16	Malmesbury	1	S	12			5	1.25	0.25	0.5	NA	0	0	9
G.van Zyl	July	16	Malmesbury	1	S	13			4	1	0	0	NA	0	0	12
G.van Zyl	July	16	Malmesbury	1	S	14			4	0.5	0	0.25	NA	0	0	11.5
G.van Zyl	July	16	Malmesbury	1	S	15	Dead	V								
G.van Zyl	July	16	Malmesbury	1	S	17	Lost									
G.van Zyl	July	16	Malmesbury	1	S	18			1	0.25	0	0	NA	1	0	17
G.van Zyl	July	16	Malmesbury	1	S	19			2	0.5	0	0.25	NA	0	0	11.5
G.van Zyl	July	16	Malmesbury	1	S	20	Dead	V								
J.Smith	April	0	Wellington	1	1H	13			9	1.5	0	0.5	Y	0	0	2.4
J.Smith	April	0	Wellington	1	1H	1			7	0.375	0	0.375	Y	0	0	2.3
J.Smith	April	0	Wellington	1	1H	16			8	0.75	0	0.1875	Y	0	0	5
J.Smith	April	0	Wellington	1	1H	20			9	0.8125	0	0.25	Y	0	0	1.1
J.Smith	April	0	Wellington	1	1H	2			13	0.5625	0	0.125	Y	0	4.5	8.8
J.Smith	April	0	Wellington	1	1H	25			12.5	0.75	0	0.25	Y	0	4.5	3.7
J.Smith	April	0	Wellington	1	1H	23			13.5	0.75	0	0.3125	Y	0	4.5	4.6
J.Smith	April	0	Wellington	1	1H	19			6	1.5	0	0.4375	NA	0	0	0.8
J.Smith	April	0	Wellington	1	1H	31			6	0.875	0	0.375	Y	0	0	1.4
J.Smith	April	0	Wellington	1	1H	32			6	1.5	0	0.1875	Y	0	0	4.3
J.Smith	April	0	Wellington	1	1H	33			5	0.5625	0	0.5625	Y	0	0	1.7
J.Smith	April	0	Wellington	1	1H	10			12	1.75	0	0.9375	Y	0	4.5	2.4
J.Smith	April	0	Wellington	1	1H	12			13.5	1	0	0.6875	Y	0	4.5	3.5
J.Smith	April	0	Wellington	1	1H	11			14.5	2.25	0.0625	1.4375	Y	0	4.5	2
J.Smith	April	0	Wellington	1	1H	22			13.5	2.5625	0	1.625	Y	0	4.5	3.7
J.Smith	April	0	Wellington	1	1H	4			7	1.33	0	0.4375	Y	0	4.5	1.7
J.Smith	April	0	Wellington	1	1H	5			10	1.5	0	1.75	NA	0	4.5	8.3
J.Smith	April	0	Wellington	1	1H	3			10.5	1.25	0	1	Y	0	4.5	3.2
J.Smith	April	0	Wellington	1	1H	21			15	1.5625	0	0.5	Y	0	4.5	2.5

J.Smith	April	0	Wellington	1	1H	6			6	1.5	0	0.4375	Y	0	0	3.6
J.Smith	July	3	Wellington	1	S	4			10	1.25	0	0.125	Y	0	0	3.8
J.Smith	July	3	Wellington	1	S	5			13	1.375	0.0625	0.3125	Y	0	0	4.2
J.Smith	July	3	Wellington	1	S	3			10	1.3125	0.0625	0.6875	Y	0	0	8.3
J.Smith	July	3	Wellington	1	S	22			13.5	1.125	0	0.375	Y	0	0	6.2
J.Smith	July	3	Wellington	1	S	21			12.5	2.5	0	0.125	Y	0	0	2
J.Smith	July	3	Wellington	1	S	6			9	1.9375	0	0.0625	Y	0	0	4.5
J.Smith	July	3	Wellington	1	S	11			13	1.6875	0	0.125	Y	0	0	5.8
J.Smith	July	3	Wellington	1	S	10			11.5	2.0625	0	0.125	Y	0	0	5.3
J.Smith	July	3	Wellington	1	S	12			12	0.6875	0	0.0625	Y	0	0	4
J.Smith	July	3	Wellington	1	S	57			6	2	0	0.0625	N	10	0	16.7
J.Smith	July	3	Wellington	1	S	2			14	2.125	0.0625	0.0625	Y	0	0	12
J.Smith	July	3	Wellington	1	S	25			13	2.5	0	0.0625	Y	0	0	4.3
J.Smith	July	3	Wellington	1	S	16			11.5	2.625	0.0625	0.125	Y	0	0	1.7
J.Smith	July	3	Wellington	1	S	23			13	2.75	0.0625	0.0625	Y	0	0	7.3
J.Smith	July	3	Wellington	1	S	13			12.5	2.375	0.0625	0.125	Y	0	0	6.2
J.Smith	July	3	Wellington	1	S	20			13	2.8125	0.0625	0.0625	Y	0	0	1.8
J.Smith	July	3	Wellington	1	S	1			8	0.625	0	0.0625	Y	0	0	4.4
J.Smith	July	3	Wellington	1	S	31			10	3.5625	0.0625	0.1875	Y	0	0	2
J.Smith	July	3	Wellington	1	S	32			8	1.75	0	0.0625	Y	0	0	2.2
J.Smith	July	3	Wellington	1	S	33			8	2.8125	0	0.125	Y	4	0	0.8
J.Smith	Oct	6	Wellington	1	1P	32			10.5	1	0	0.3125	Y	0	0	6
J.Smith	Oct	6	Wellington	1	1P	31			9.5	2.875	0.0625	0.5625	Y	0	0	2
J.Smith	Oct	6	Wellington	1	1P	33			14.5	2.625	0.125	1.3125	Y	0	0	5.4
J.Smith	Oct	6	Wellington	1	1P	2			12	.	0	0.3125	Y	0	0	9.3
J.Smith	Oct	6	Wellington	1	1P	1			12.5	0.5	0	0.1875	N	0	0	7.5
J.Smith	Oct	6	Wellington	1	1P	16			14.5	2.125	0	0.9375	Y	0	0	10
J.Smith	Oct	6	Wellington	1	1P	20			14.5	3.375	0.0625	0.25	Y	0	0	0.9
J.Smith	Oct	6	Wellington	1	1P	23			12.5	2.625	0.0625	0.5	Y	0	0	13.4
J.Smith	Oct	6	Wellington	1	1P	13			14	1.875	0.0625	0.625	Y	0	0	24.9
J.Smith	Oct	6	Wellington	1	1P	25			11	0.3125	0	1	N	0	0	7.8
J.Smith	Oct	6	Wellington	1	1P	57			3.5	1.5	0	0.125	Y	0	0	5.2
J.Smith	Oct	6	Wellington	1	1P	10			12.5	2.625	0.0625	0.1875	Y	0	0	10.7
J.Smith	Oct	6	Wellington	1	1P	12			13.5	2	0.0625	0.1875	Y	0	0	6
J.Smith	Oct	6	Wellington	1	1P	11			14	2.5	0.0625	0.5	Y	0	0	10
J.Smith	Oct	6	Wellington	1	1P	4			12.5	2.875	0.0625	0	Y	0	0	5.4
J.Smith	Oct	6	Wellington	1	1P	5			11	1.3125	0	0.625	Y	0	0	2.2
J.Smith	Oct	6	Wellington	1	1P	6			4.5	1.5625	0.0625	0.0625	Y	0	0	6.2
J.Smith	Oct	6	Wellington	1	1P	3			8	0.125	0	0.125	N	1	0	13.6
J.Smith	Oct	6	Wellington	1	1P	22			10	1	0.0625	0.1875	N	2	0	13.5
J.Smith	Oct	6	Wellington	1	1P	21			12	4.25	0	0.3125	Y	0	0	5.4
A.Beverley	April	0	Paarl	1	S	1			9	1.3125	0.0625	0	Y	0	4	2.3
A.Beverley	April	0	Paarl	1	S	2			11	0.375	0	0.0625	Y	0	5	6
A.Beverley	April	0	Paarl	1	S	3			6	0.5	0	0.75	Y	0	5	7.6
A.Beverley	April	0	Paarl	1	S	4			8	1.0625	0	0.25	Y	0	5	2.7
A.Beverley	April	0	Paarl	1	S	5			7	0.125	0	0.0625	Y	0	6	8.4
A.Beverley	April	0	Paarl	1	S	6			7	1.25	0	0.4375	Y	0	3	9
A.Beverley	April	0	Paarl	1	S	7			7	0.5	0	0.375	Y	0	6	1
A.Beverley	April	0	Paarl	1	S	8			6	0.75	0	0	Y	0	6	3.3
A.Beverley	April	0	Paarl	1	S	9			8	0.1875	0	0.0625	Y	0	3	13.3
A.Beverley	April	0	Paarl	1	S	10			5	0.125	0	0.0625	NA	0	6	10

A.Beverley	April	0	Paarl	1	S	11			9	0.125	0	0.375	Y	0	3	8.3
A.Beverley	April	0	Paarl	1	S	12			7	0.625	0	0.375	Y	0	5	12.3
A.Beverley	April	0	Paarl	1	S	13			7	0.0625	0	0.5	Y	0	3	15
A.Beverley	April	0	Paarl	1	S	14			6	0	0	0.5625	NA	0	0	14.5
A.Beverley	April	0	Paarl	1	S	15			8	0	0	0.0625	Y	0	8	5.3
A.Beverley	April	0	Paarl	1	S	16			9	0.25	0	0.1875	Y	0	0	10.7
A.Beverley	April	0	Paarl	1	S	17			6	0.25	0	0	Y	0	0	10.4
A.Beverley	April	0	Paarl	1	S	18			9	0.25	0	2.375	Y	0	5	7.3
A.Beverley	April	0	Paarl	1	S	19			6	1	0	0.8125	Y	0	6	17.3
A.Beverley	April	0	Paarl	1	S	20			8	0.3125	0	0.25	Y	0	7	14.3
A.Beverley	Jan	9	Paarl	1	1P	1			11	2.0625	0	1	Y	0	0	4.4
A.Beverley	Jan	9	Paarl	1	1P	2			14.5	2.3125	0.0625	0.5	Y	0	0	2.9
A.Beverley	Jan	9	Paarl	1	1P	3			11	0.4375	0	0.375	Y	1	0	7.9
A.Beverley	Jan	9	Paarl	1	1P	4			12	1.4375	0	0.4375	Y	0	0	3.9
A.Beverley	Jan	9	Paarl	1	1P	5			8	1.625	0	0.25	Y	0	0	0.5
A.Beverley	Jan	9	Paarl	1	1P	6			10.5	2.5	0.0625	0.75	Y	0	0	2.3
A.Beverley	Jan	9	Paarl	1	1P	7			NA	3.3125	0.5	0.375	Y	0	0	4.4
A.Beverley	Jan	9	Paarl	1	1P	8			6	1.125	0.125	0.3125	Y	1	0	2.5
A.Beverley	Jan	9	Paarl	1	1P	9			5	1.5625	0.125	0.1875	Y	0	0	3.1
A.Beverley	Jan	9	Paarl	1	1P	10			3	0.375	0	0	Y	1	0	6.2
A.Beverley	Jan	9	Paarl	1	1P	11			14	1.9375	0.0625	0.25	Y	0	0	4.3
A.Beverley	Jan	9	Paarl	1	1P	12			5	2.6875	0.0625	0.5	Y	0	10	5.3
A.Beverley	Jan	9	Paarl	1	1P	13			9.5	1.8125	0.3125	0.0625	Y	0	0	10
A.Beverley	Jan	9	Paarl	1	1P	14	Dead	V								
A.Beverley	Jan	9	Paarl	1	1P	15			13.5	1.875	0	0.25	Y	0	0	4.3
A.Beverley	Jan	9	Paarl	1	1P	16	Dead	U								
A.Beverley	Jan	9	Paarl	1	1P	17			3	0.25	0	0.125	N	0	0	1
A.Beverley	Jan	9	Paarl	1	1P	18			8	1.25	0	0.3125	Y	0	0	7.1
A.Beverley	Jan	9	Paarl	1	1P	19	Dead	U								
A.Beverley	Jan	9	Paarl	1	1P	20	Dead	U								
A.Beverley	May	13	Paarl	1	S	1			4	0.25	0	0.3175	Y	0	0	12.5
A.Beverley	May	13	Paarl	1	S	2			6	1	0	1.25	Y	0	0	1.67
A.Beverley	May	13	Paarl	1	S	3	Dead	U								
A.Beverley	May	13	Paarl	1	S	4			4	1.25	0	1.25	Y	0	0	7
A.Beverley	May	13	Paarl	1	S	5			8	1	0	1.25	Y	0	0	2
A.Beverley	May	13	Paarl	1	S	6			4	1	0	0.75	Y	0	0	8.8
A.Beverley	May	13	Paarl	1	S	7	Dead	U								
A.Beverley	May	13	Paarl	1	S	8			5	NA	0	1.125	NA	1	0	5
A.Beverley	May	13	Paarl	1	S	9			4	0.1875	0	0.5	Y	0	0	14.67
A.Beverley	May	13	Paarl	1	S	10	Dead	U								
A.Beverley	May	13	Paarl	1	s	11	Dead	U								
A.Beverley	May	13	Paarl	1	S	12			9	1	0	1	Y	0	0	6.3
A.Beverley	May	13	Paarl	1	S	13			3	0.125	0.475	0	Y	0	0	14.67
A.Beverley	May	13	Paarl	1	S	15			6	0.5	0	0.75	Y	0	0	3
A.Beverley	May	13	Paarl	1	S	17	Dead	U								
A.Beverley	May	13	Paarl	1	S	18			7	0.325	0	0.875	Y	0	0	6.57
N. Langen	Jan	0	Porterville	3	S	1			NA	5	0	2	Y	0	15kg	2.6
N. Langen	Jan	0	Porterville	3	S	2			NA	3	0	0.5	Y	0	10kg	6
N. Langen	Jan	0	Porterville	3	S	3			NA	5	0	2	Y	0	15kg	1.6
N. Langen	Jan	0	Porterville	3	S	4			NA	2.5	0	3	Y	0	15kg	0.6
N. Langen	Jan	0	Porterville	3	S	5			NA	2.5	0	3	Y	0	20kg	3

N. Langen	Jan	0	Porterville	3	S	6			NA	4	0	3	Y	0	50kg	1
N. Langen	Jan	0	Porterville	3	S	7			NA	6	0	0	Y	0	10kg	2.8
N. Langen	Jan	0	Porterville	3	S	8			NA	3.5	0	0.5	Y	0	10kg	11.8
N. Langen	Jan	0	Porterville	3	S	9			NA	3	0.25	1	Y	0	20kg	2.8
N. Langen	Jan	0	Porterville	3	S	10			NA	2	0.25	0	Y	0	0kg	0.4
N. Langen	Jan	0	Worcester	1	S	11			NA	5.5	0	2	Y	0	20kg	0.8
N. Langen	Jan	0	Worcester	1	S	12			NA	2	0.25	3	Y	0	10kg	3
N. Langen	Jan	0	Worcester	1	S	13			NA	0.75	0	2	Y	0	0kg	8.6
N. Langen	Jan	0	Worcester	1	S	14			NA	6	0	1	Y	0	20kg	3.2
N. Langen	Jan	0	Worcester	1	S	15			NA	7	0	1	Y	0	20kg	7.2
N. Langen	Jan	0	Worcester	1	S	16			NA	4	0	1	Y	0	10kg	2
N. Langen	Jan	0	Worcester	1	S	17			NA	3	0	1	Y	0	10kg	2.2
N. Langen	Jan	0	Worcester	1	S	18			NA	1.5	0	0.5	Y	0	10kg	3.6
N. Langen	Jan	0	Worcester	1	S	19			NA	3.5	0	1	Y	0	30kg	6.2
N. Langen	Jan	0	Worcester	1	S	20			NA	4	0	1	Y	0	30kg	2.6
N. Langen	Jan	0	Breerivier	1	S	21			NA	2	0	1	Y	0	24	2.2
N. Langen	Jan	0	Breerivier	1	S	22			NA	1.5	0	3	Y	2	12	0.8
N. Langen	Jan	0	Breerivier	1	S	23			NA	7	0.25	1	Y	0	36	0.8
N. Langen	Jan	0	Breerivier	1	S	24			NA	4	0	1	Y	0	24	0.2
N. Langen	Jan	0	Breerivier	1	S	25			NA	5	0	1	Y	0	12	1.8
N. Langen	Jan	0	Breerivier	1	S	26			NA	1.2	0	0.5	Y	0	24	2.6
N. Langen	Jan	0	Breerivier	1	S	27			NA	5	0	1	Y	0	36	0.8
N. Langen	Jan	0	Breerivier	1	S	28			NA	5	0	1	Y	0	24	4.8
N. Langen	Jan	0	Breerivier	1	S	29			NA	5	0.5	1	Y	0	24	0.6
N. Langen	Jan	0	Breerivier	1	S	30			NA	4	0.4	1	Y	0	12	0.6
N. Langen	Jan	0	Slanghoek	1	S	31			NA	3	0	2	Y	0	12	3.6
N. Langen	Jan	0	Slanghoek	1	S	32			NA	4	0	2	Y	0	24	4.8
N. Langen	Jan	0	Slanghoek	1	S	33			NA	4	0	1	Y	0	30	1.2
N. Langen	Jan	0	Slanghoek	1	S	34			NA	5	0	1	Y	0	12	1.4
N. Langen	Jan	0	Slanghoek	1	S	35			NA	3.5	0	3.5	Y	0	12	0.8
N. Langen	Jan	0	Slanghoek	1	S	36			NA	4.5	0	1.5	Y	0	24	0.8
N. Langen	Jan	0	Slanghoek	1	S	37			NA	5	0	2.5	Y	0	24	0
N. Langen	Jan	0	Slanghoek	1	S	38			NA	4.5	0	2	Y	0	12	0
N. Langen	Jan	0	Slanghoek	1	S	39			NA	2	0	1	Y	0	12	2.8
N. Langen	Jan	0	Slanghoek	1	S	40			NA	3	0	2	Y	0	24	9
N. Langen	Jan	0	Malmesbury	2	S	41			NA	2.4	0.25	1	Y	0	0	5
N. Langen	Jan	0	Malmesbury	2	S	42			NA	6.5	0	0.25	Y	0	0	0.4
N. Langen	Jan	0	Malmesbury	2	S	43			NA	2.5	0	0.25	Y	0	11	2.2
N. Langen	Jan	0	Malmesbury	2	S	44			NA	4.5	0	0.25	Y	0	11	5.8
N. Langen	Jan	0	Malmesbury	2	S	45			NA	4	0	2	Y	0	22	1.8
N. Langen	Jan	0	Malmesbury	2	S	46			NA	4	0	1	Y	0	0	0.4
N. Langen	Jan	0	Malmesbury	2	S	47			NA	2	0	1	Y	0	0	1
N. Langen	Jan	0	Malmesbury	2	S	48			NA	2.5	0	0	Y	0	11	3.8
N. Langen	Jan	0	Malmesbury	2	S	49			NA	2	0	1	Y	0	0	1
N. Langen	Jan	0	Malmesbury	2	S	50			NA	5	0	1	Y	0	22	3
N. Langen	Jan	0	Malmesbury	2	S	51			NA	3	0	0.5	Y	0	11	0.4
N. Langen	Jan	0	Malmesbury	2	S	52			NA	1.5	0	0	Y	0	0	0.4
N. Langen	Jan	0	Malmesbury	2	S	53			NA	NA	0	0	Y	0	11	0.2
N. Langen	Jan	0	Malmesbury	2	S	54			NA	NA	0	0	Y	0	11	0.6
N. Langen	Jan	0	Malmesbury	2	S	55			NA	NA	0	1	Y	0	22	0.8
N. Langen	Jan	0	Malmesbury	2	S	56			NA	NA	0	0.5	Y	0	11	0.8
N. Langen	Jan	0	Malmesbury	2	S	57			NA	NA	0	1	Y	0	11	1.4

N. Langen	Jan	0	Malmesbury	2	S	58			NA	NA	0	0.5	Y	0	11	3
N. Langen	Jan	0	Malmesbury	2	S	59			NA	NA	0	1	Y	0	22	6.8
N. Langen	Jan	0	Malmesbury	2	S	60			NA	NA	0	1	Y	0	11	0.2
N. Langen	April	2	Porterville	2	S	1			7	2.375	0	0.125	Y	0	4	1.1
N. Langen	April	2	Porterville	2	S	2			6	0.25	0	0.125	N	1	4	4.6
N. Langen	April	2	Porterville	2	S	3			7	1.625	0	0.33	Y	0	4	6.2
N. Langen	April	2	Porterville	2	S	4			4	2	0	0.705	Y	0	7	1.5
N. Langen	April	2	Porterville	2	S	5			5	1.875	0	0.375	Y	0	3.5	4
N. Langen	April	2	Porterville	2	S	6			8	2	0	0.25	Y	0	6	1.3
N. Langen	April	2	Porterville	2	S	7			2	2	0	0.125	Y	0	4.5	2.7
N. Langen	April	2	Porterville	2	S	8			6	1.25	0	0	Y	0	4	1.6
N. Langen	April	2	Porterville	2	S	9			7	1.875	0	0	Y	0	4.5	6.2
N. Langen	April	2	Porterville	2	S	10			5	1.625	0	0.5	Y	0	3	0.2
N. Langen	April	3	Malm/Rie	2	S	11			5	1.41	0	1	Y	0	0	2.7
N. Langen	April	3	Malm/Rie	2	S	12			4	1	0	0.375	Y	0	0	8.9
N. Langen	April	3	Malm/Rie	2	S	13			NA	0.25	0	1.41	Y	0	0	8.3
N. Langen	April	3	Malm/Rie	2	S	14			NA	0.25	0	0.125	Y	0	0	11.6
N. Langen	April	3	Malm/Rie	2	S	15			4	0.125	0	0.0625	Y	0	0	14.7
N. Langen	April	3	Malm/Rie	2	S	16			6	0.625	0	0.125	Y	0	0	14.2
N. Langen	April	3	Malm/Rie	2	S	17			9	0.75	0	0	N	13	0	8
N. Langen	April	3	Malm/Rie	2	S	18			4	1.125	0	0.125	Y	0	0	6.9
N. Langen	April	3	Malm/Rie	2	S	19			5	0.75	0	0.6875	Y	0	0	12.5
N. Langen	April	3	Malm/Rie	2	S	20			5	1	0	1.125	Y	0	0	15.1
N. Langen	April	2	Breerivier	1	S	21			9	0.25	0	0.875	Y	0	10	5.8
N. Langen	April	2	Breerivier	1	S	22			6	1	0	2.5	Y	0	5	NA
N. Langen	April	2	Breerivier	1	S	23			7	3.125	0	0.25	Y	0	10	3.6
N. Langen	April	2	Breerivier	1	S	24			8	3	0	0.5	Y	0	10	1.3
N. Langen	April	2	Breerivier	1	S	25			6	1.875	0	0.5	Y	0	5	0.9
N. Langen	April	2	Breerivier	1	S	26			4	1.125	0	1.375	Y	0	4	5.5
N. Langen	April	2	Breerivier	1	S	27			11	1.75	0	1	Y	0	12	4.5
N. Langen	April	2	Breerivier	1	S	28			8	2.375	0	0.75	Y	0	10	6.5
N. Langen	April	2	Breerivier	1	S	29			9	2.5	0	0.625	Y	0	10	2
N. Langen	April	2	Breerivier	1	S	30			8	2	0	1.375	Y	0	10	4.4
N. Langen	April	2	Wor/Slang	2	S	31			7	2.5	0	0.8	Y	0	5	6.2
N. Langen	April	2	Wor/Slang	2	S	32			5	2.875	0	0.625	Y	0	5	10.4
N. Langen	April	2	Wor/Slang	2	S	33			6	3.75	0	1.125	Y	0	8	0.7
N. Langen	April	2	Wor/Slang	2	S	34			6	3.5	0	1.5	Y	0	9	4
N. Langen	April	2	Wor/Slang	2	S	35			7	3.75	0	0.125	Y	0	9.5	4.7
N. Langen	April	2	Wor/Slang	2	S	36			5	4	0	0.5	Y	0	2.5	0.9
N. Langen	April	2	Wor/Slang	2	S	37			8	4.125	0	0.5	Y	0	10	0.9
N. Langen	April	2	Wor/Slang	2	S	38			7	3.25	0	0.25	Y	0	10	0.2
N. Langen	April	2	Wor/Slang	2	S	39			5	3.25	0	0.375	Y	0	8	3.6
N. Langen	April	2	Wor/Slang	2	S	40			6	2.375	0	1.125	Y	0	9	9.8
N. Langen	April	3	Malm/Rie	2	S	41			5	0.625	0	0.125	Y	0	10	16.4
N. Langen	April	3	Malm/Rie	2	S	42			5	0.375	0	0.375	Y	0	10	7.3
N. Langen	April	3	Malm/Rie	2	S	43			6	0.5	0	0	Y	0	5	9.3
N. Langen	April	3	Malm/Rie	2	S	44			6	1	0	0	Y	0	5	20.2
N. Langen	April	3	Malm/Rie	2	S	45			6	0.625	0	0	Y	0	5	3.8
N. Langen	April	3	Malm/Rie	2	S	46			7	0	0	0	Y	0	10	4.5
N. Langen	April	3	Malm/Rie	2	S	47			1	NA	0	0	NA	0	0	NA
N. Langen	April	3	Malm/Rie	2	S	48			5.5	0.625	0	0	Y	0	5	17.1
N. Langen	April	3	Malm/Rie	2	S	49			5	0.375	0	0	Y	0	5	9.3

N. Langen	April	3	Malm/Rie	2	S	50			6	0.75	0	0	Y	0	5	12.3
N. Langen	April	3	Malm/Darl	2	S	51			5	1.625	0	0.375	Y	0	5	8.5
N. Langen	April	3	Malm/Darl	2	S	52			4	1.25	0	0.25	Y	0	2	2.5
N. Langen	April	3	Malm/Darl	2	S	53			6	2.25	0	1.125	Y	0	5	1.3
N. Langen	April	3	Malm/Darl	2	S	54			5	1.25	0	0.25	Y	0	4	2.6
N. Langen	April	3	Malm/Darl	2	S	55			4	1.625	0	0.25	Y	0	4.5	4.2
N. Langen	April	3	Malm/Darl	2	S	56			6	2.25	0	0.125	Y	0	4	3.9
N. Langen	April	3	Malm/Darl	2	S	57			4	2	0	0.125	Y	0	1	NA
N. Langen	April	3	Malm/Darl	2	S	58			6	0	0	0	Y	0	5	6.5
N. Langen	April	3	Malm/Darl	2	S	59			7	1.25	0	0.25	Y	0	5	9.3
N. Langen	April	3	Malm/Darl	2	S	60			6	1	0	0.25	Y	0	5	5.3
N. Langen	April	3	Klapmuts	1	S	61			7	1.875	0.125	0	Y	0	5	12
N. Langen	April	3	Klapmuts	1	S	62			6	1.25	0	0	Y	0	5	10.2
N. Langen	April	3	Klapmuts	1	S	63			6	1.875	0	0	Y	0	6	13.6
N. Langen	April	3	Klapmuts	1	S	64			8	2.375	0	0	Y	0	7.5	14.2
N. Langen	April	3	Klapmuts	1	S	65			4	1.25	0.125	0	Y	0	5	25.8
N. Langen	April	3	Klapmuts	1	S	66			5	2.375	0.125	0	Y	0	5	8.4
N. Langen	April	3	Klapmuts	1	S	67			6	2	0	0	Y	0	5	3.5
N. Langen	April	3	Klapmuts	1	S	68			3	1.5	0.375	0	Y	0	4	1.5
N. Langen	April	3	Klapmuts	1	S	69			6	2.5	0	0	Y	0	5.5	8.4
N. Langen	April	3	Klapmuts	1	S	70			7	1.625	0	0	Y	0	7	10.9
N. Langen	May	4	Wor/Slang	1	1H	1			2	1.625	0	0.125	Y	0	0	2
N. Langen	May	4	Wor/Slang	1	1H	2			NA	0.625	0	0.1875	Y	0	0.5	2
N. Langen	May	4	Wor/Slang	1	1H	3			2	0.625	0	0.0625	Y	0	0	7.3
N. Langen	May	4	Wor/Slang	1	1H	4			NA	1.625	0	0.875	NA	0	0	0.7
N. Langen	May	4	Wor/Slang	1	1H	5			3	1.375	0	0.25	Y	0	0	2
N. Langen	May	4	Wor/Slang	1	1H	6			5	2.625	0	0.25	Y	0	0	1.7
N. Langen	May	4	Wor/Slang	1	1H	7			7	2.375	0	0.1875	Y	0	0.5	2.3
N. Langen	May	4	Wor/Slang	1	1H	8			3	1.375	0	0.0625	Y	0	0.5	5.4
N. Langen	May	4	Wor/Slang	1	1H	9			6	2.5	0	0.0625	Y	0	0.5	4.3
N. Langen	May	4	Wor/Slang	1	1H	10			5	1.25	0	0.5626	Y	0	0.5	0.6
N. Langen	May	4	Wor/Bree	1	S	21			4	1.5	0.125	0	Y	0	0	3.2
N. Langen	May	4	Wor/Bree	1	S	22			5	1.5	1.75	1	Y	0	0	6.5
N. Langen	May	4	Wor/Bree	1	S	23			8	2.625	0	0.1875	Y	0	0	3
N. Langen	May	4	Wor/Bree	1	S	24			6	2.75	0	0.25	Y	0	0	1.1
N. Langen	May	4	Wor/Bree	1	S	25			8	1.75	0	0.1875	Y	0	0	1.7
N. Langen	May	4	Wor/Bree	1	S	26			3	1	0	0.3125	Y	0	0	6.6
N. Langen	May	4	Wor/Bree	1	S	27			9	2.0625	0	0.25	Y	0	0	5.8
N. Langen	May	4	Wor/Bree	1	S	28			6	2.375	0	0.5625	Y	0	4	2.3
N. Langen	May	4	Wor/Bree	1	S	29			9	2.875	0.0625	0.125	Y	0	4	1.3
N. Langen	May	4	Wor/Bree	1	S	30			4	2.4375	0.0625	0.3125	Y	0	4	5
N. Langen	May	4	Wor/Slang	1	S	31			6	2.5	0	0.875	Y	0	0	4.6
N. Langen	May	4	Wor/Slang	1	S	32			5	2.875	0	0.625	Y	0	0	14.5
N. Langen	May	4	Wor/Slang	1	S	33			7	3.75	0	1.125	Y	0	3	1.4
N. Langen	May	4	Wor/Slang	1	S	34			9	3.25	0	1.5	Y	0	3	8.8
N. Langen	May	4	Wor/Slang	1	S	35			9	3.75	0	0.125	Y	0	8	5
N. Langen	May	4	Wor/Slang	1	S	36			9	4	0	0.875	Y	0	0	2.6
N. Langen	May	4	Wor/Slang	1	S	37			11	4.125	0	0.25	Y	0	8	0.6
N. Langen	May	4	Wor/Slang	1	S	38			10	3.25	0	0.25	Y	0	8	1
N. Langen	May	4	Wor/Slang	1	S	39			3	3.25	0	0.375	NA	0	0	4.6
N. Langen	May	4	Wor/Slang	1	S	40			3	1.875	0	1.125	Y	0	0	5
N. Langen	Sept	8	Malmesbury	2	S	11			6	2.25	0.625	2.375	Y	0	2	0.8

N. Langen	Sept	8	Malmesbury	2	S	12			6	3.375	0.0938	0.1875	Y	0	0	2.2
N. Langen	Sept	8	Malmesbury	2	S	13			8	4.125	0.1875	0.6875	Y	0	0	0.8
N. Langen	Sept	8	Malmesbury	2	S	14			6	3.25	0.5	0.625	Y	0	0	0.8
N. Langen	Sept	8	Malmesbury	2	S	15			7	3.625	0.0625	0.6875	Y	0	0	2.2
N. Langen	Sept	8	Malmesbury	2	S	16			9	3.125	0.3125	1.375	Y	0	0	1
N. Langen	Sept	8	Malmesbury	2	S	17			6	3.625	0.375	0.3125	Y	0	0	0.5
N. Langen	Sept	8	Malmesbury	2	S	18			6	4	0.75	0.75	Y	0	0	0.5
N. Langen	Sept	8	Malmesbury	2	S	19			9	5.5	0.4375	1.125	Y	0	0	1.2
N. Langen	Sept	8	Malmesbury	2	S	20			7	4	0.4375	0.625	Y	0	0	1.4
N. Langen	Sept	8	Malmesbury	2	S	21			8	4.75	0.125	0.4375	Y	0	0	0.2
N. Langen	Sept	8	Malmesbury	2	S	22			4	1.5	0	0.435	Y	0	0	5.3
N. Langen	Sept	8	Malmesbury	2	S	23			11	1.8125	0.125	0.25	Y	0	0	0.3
N. Langen	Sept	8	Malmesbury	2	S	24			10	3.25	0	0.0625	Y	0	0	0.5
N. Langen	Sept	8	Malmesbury	2	S	25			10	1.5	0	1	Y	0	0	0.8
N. Langen	Sept	8	Malmesbury	2	S	26			3	1.5	0	0.625	Y	0	0	1.2
N. Langen	Sept	8	Malmesbury	2	S	27			12	4.5	0	0.3125	Y	0	0	3.8
N. Langen	Sept	8	Malmesbury	2	S	28			11.5	4.75	0.125	0.4375	Y	0	0	2.4
N. Langen	Sept	8	Malmesbury	2	S	29			11.5	4.625	0.5	0.375	Y	0	0	2.2
N. Langen	Sept	8	Malmesbury	2	S	30			10	5.125	0	0.375	Y	0	0	1.2
N. Langen	Sept	8	Wor/Slang	1	S	31			8	5.25	1.0625	0.8125	Y	0	0	2.8
N. Langen	Sept	8	Wor/Slang	1	S	32			8	4.375	0.0625	0.9375	Y	0	0	10.7
N. Langen	Sept	8	Wor/Slang	1	S	33			10	4.5	0.1875	0.875	Y	0	0	1
N. Langen	Sept	8	Wor/Slang	1	S	34			11.5	4.625	0.375	1.3125	Y	0	0	2
N. Langen	Sept	8	Wor/Slang	1	S	35			12	5.5	0.125	1.125	Y	0	0	4.5
N. Langen	Sept	8	Wor/Slang	1	S	36			6	0.5	0	0.375	Y	0	0	6.6
N. Langen	Sept	8	Wor/Slang	1	S	37			12.5	5.25	0.0625	0.8125	Y	0	0	1.8
N. Langen	Sept	8	Wor/Slang	1	S	38			12	4.5	0.125	1.5	Y	0	0	0.2
N. Langen	Sept	8	Wor/Slang	1	S	39			5	2.25	0	0.8125	Y	0	0	2.4
N. Langen	Sept	8	Wor/Slang	1	S	40			10	3.375	0	0.125	Y	0	0	2.5
N. Langen	Sept	8	Malm/Rie	2	S	41			9	3.66	0.955	1	Y	0	0	7.5
N. Langen	Sept	8	Malm/Rie	2	S	42			8	4.83	0.705	0.75	Y	1	0	1.3
N. Langen	Sept	8	Malm/Rie	2	S	43			4	2.5	0	0.625	Y	0	0	0.8
N. Langen	Sept	8	Malm/Rie	2	S	44	Dead	U								
N. Langen	Sept	8	Malm/Rie	2	S	45			6	1.83	0	2.955	Y	0	1	0.5
N. Langen	Sept	8	Malm/Rie	2	S	46			6	1.583	0.25	1.875	Y	3	0	3.6
N. Langen	Sept	8	Malm/Rie	2	S	47	Dead	U								
N. Langen	Sept	8	Malm/Rie	2	S	48			8	5.25	0.4375	1.125	Y	0	0	3.7
N. Langen	Sept	8	Malm/Rie	2	S	49			10	4.625	0.4375	0.875	Y	0	0	1
N. Langen	Sept	8	Malm/Rie	2	S	50			7	4.75	0.583	1.375	Y	2	0	4.7
N. Langen	Sept	8	Malm/Rie	2	S	51			5	2.625	0.125	0.125	Y	0	0.5	4.6
N. Langen	Sept	8	Malm/Rie	2	S	52			6	4.125	0.0625	0.375	Y	0	0.5	3.1
N. Langen	Sept	8	Malm/Rie	2	S	53			7	4.375	0.3125	0.75	Y	0	0	1.3
N. Langen	Sept	8	Malm/Rie	2	S	54			9	5.25	0.125	0.8125	Y	0	1	2.4
N. Langen	Sept	8	Malm/Rie	2	S	55			0.5	0.75	0	0.5	Y	0	0	1.7
N. Langen	Sept	8	Malm/Rie	2	S	56			4	2.75	0	0.3125	Y	0	0	2.8
N. Langen	Sept	8	Malm/Rie	2	S	57			8	4.5	0	0.375	Y	0	0	3.8
N. Langen	Sept	8	Malm/Rie	2	S	58			6	3.5	0	1	Y	0	0	3.3
N. Langen	Sept	8	Malm/Rie	2	S	59			8	5.375	0	0.4375	Y	0	0.5	4.2
N. Langen	Sept	8	Malm/Rie	2	S	60			8	4.875	0.0625	0.375	Y	0	0.5	4.7
N. Langen	Sept	8	Malm/Rie	2	S	61			11	4.875	0.3125	0.4375	Y	0	0	2.4
N. Langen	Sept	8	Malm/Rie	2	S	62			10.5	3.125	0.0625	1.375	Y	2	0	3.3
N. Langen	Sept	8	Malm/Rie	2	S	63			10	4.625	0.375	0.375	Y	0	0	5

N. Langen	Sept	8	Malm/Rie	2	S	64			0.5	0.5625	0	0	Y	0	0	8.7
N. Langen	Sept	8	Malm/Rie	2	S	65			9	4.75	0.0625	0.6875	Y	0	0	7.3
N. Langen	Sept	8	Malm/Rie	2	S	66	Dead	U								
N. Langen	Sept	8	Malm/Rie	2	S	67			11.5		0.0625	0.75	Y	0	0	3.7
N. Langen	Sept	8	Malm/Rie	2	S	68			9	3.6875	0	2.125	Y	0	0	0.8
N. Langen	Sept	8	Malm/Rie	2	S	69			8	3.75	0.25	0.8125	Y	0	0	1.6
N. Langen	Sept	8	Malm/Rie	2	S	70			7	4	0	1.125	Y	0	0	6
N. Langen	Dec	11	Bergrivier	3	S	17			8	5.125	1.25	1.9375	Y	0	0	6
N. Langen	Dec	11	Bergrivier	3	S	23			7	4.75	0.1875	1.375	Y	0	0	7
N. Langen	Dec	11	Bergrivier	3	S	25			5	5.5	0.25	0.5625	Y	0	0	7
N. Langen	Dec	11	Bergrivier	3	S	30			8	4.5	0.0563	0.75	Y	0	0	4
N. Langen	Dec	11	Bergrivier	3	S	31			7	3.9375	0	0.1875	Y	0	0	12.3
N. Langen	Dec	11	Bergrivier	3	S	32			4	2.75	0	0.875	NA	0	0	17.7
N. Langen	Dec	11	Bergrivier	3	S	34			20	5.625	0.25	2.1875	N	0	0	10.6
N. Langen	Dec	11	Bergrivier	3	S	35			6	3.75	0	1.25	Y	0	0	14.9
N. Langen	Dec	11	Bergrivier	3	S	37			10	6.125	0.0625	1.125	Y	0	0	9.7
N. Langen	Dec	11	Bergrivier	3	S	38			9	6.125	0.1875	1.1875	Y	0	0	2.9
N. Langen	Dec	11	Wor/Slang	1	S	33			4	1.3125	0	0.1625	NA	0	0	1.3
N. Langen	Dec	11	Wor/Slang	1	S	39			.	3.375	0.375	0.9375	NA	0	0	.
N. Langen	Dec	11	Wor/Slang	1	S	63			7	3.25	0	1.8125	Y	0	0	36
N. Langen	Dec	11	Wor/Slang	1	S	70			6	3.125	0	1.875	Y	0	0	10.7
N. Langen	Dec	11	Olifantsberg	3	S	24			8	3.75	0	2.25	Y	0	0	2
N. Langen	Dec	11	Olifantsberg	3	S	26			6	3.1875	0.0625	1	Y	0	0	4
N. Langen	Dec	11	Olifantsberg	3	S	27			10	4.0625	0.625	4	Y	0	5	6.3
N. Langen	Dec	11	Olifantsberg	3	S	29			9	4.75	0.125	0.625	Y	0	0	16.7
N. Langen	Dec	11	Olifantsberg	3	S	65			8	5	0.0625	1.5625	Y	0	0	21
N. Langen	Dec	11	Klapmuts	1	S	1			5	3	0.4	0.2	Y	0	0	5.8
N. Langen	Dec	11	Klapmuts	1	S	2			9	2.5	0	0.1	Y	0	2	10
N. Langen	Dec	11	Klapmuts	1	S	3			11	2.4	0.4	0.5	Y	0	0	9
N. Langen	Dec	11	Klapmuts	1	S	4	Dead	U								
N. Langen	Dec	11	Klapmuts	1	S	5			5	1.1	0	0	Y	0	0	12.3
N. Langen	Dec	11	Klapmuts	1	S	6	Dead	U								
N. Langen	Dec	11	Klapmuts	1	S	7			9	2.8	0	0	Y	0	0	10.3
N. Langen	Dec	11	Klapmuts	1	S	8	Dead	U								
N. Langen	Dec	11	Klapmuts	1	S	9	Dead	U								
N. Langen	Dec	11	Klapmuts	1	S	10	Dead	U								
N. Langen	Dec	11	Klapmuts	1	S	15			10	3.3	0.1	1.1	Y	0	7	2.5
N. Langen	Dec	11	Klapmuts	1	S	19			5	3	0	1	Y	0	0	0.8
N. Langen	Dec	11	Klapmuts	1	S	22			6	3.2	0	1.4	Y	0	0	1.3
N. Langen	Dec	11	Klapmuts	1	S	61			10	3.4	0.1	1.1	Y	0	5	8.4
N. Langen	Dec	11	Klapmuts	1	S	62	Dead	U								
N. Langen	Dec	11	Klapmuts	1	S	64			8	3	0	1.5	Y	0	0	2
N. Langen	Dec	11	Klapmuts	1	S	67			3	0.3	0	1.7	Y	0	5	6
N. Langen	Dec	11	Klapmuts	1	S	68			10	4	0	2.5	Y	0	4.5	1.4
N. Langen	Dec	11	Klapmuts	1	S	69			10	2.4	0.4	1.9	Y	0	0	1.5
N. Langen	Dec	11	Malm/Rie	2	S	41			10	4	0	1.5	Y	0	0	9
N. Langen	Dec	11	Malm/Rie	2	S	42			12	3.875	0.1875	1.0625	Y	0	0	3.3
N. Langen	Dec	11	Malm/Rie	2	S	43			8	3	0	1.3125	Y	0	0	2
N. Langen	Dec	11	Malm/Rie	2	S	45			12	3.375	0.0625	2.5	Y	0	0	4
N. Langen	Dec	11	Malm/Rie	2	S	46			3	1.25	0	1.875	Y	0	0	9
N. Langen	Dec	11	Malm/Rie	2	S	48			NA	4.5	0.125	1.75	Y	0	6.5	12.3
N. Langen	Dec	11	Malm/Rie	2	S	49			NA	3.875	0	1.6875	Y	0	6.5	8

N. Langen	Dec	11	Malm/Rie	2	S	50			NA	3.25	0	1.5	Y	0	0	7.1
N. Langen	Dec	11	Malm/Rie	2	S	51			13	2.875	0	1.125	Y	0	0	10.9
N. Langen	Dec	11	Malm/Rie	2	S	52			13	2.4375	0	1.75	Y	0	0	20.7
N. Langen	Dec	11	Malm/Rie	2	S	53			13	2.75	0	2.5	Y	0	0	12.9
N. Langen	Dec	11	Malm/Rie	2	S	54			14	2.3125	0	0.375	Y	0	0	9.8
N. Langen	Dec	11	Malm/Rie	2	S	55	Dead	U								
N. Langen	Dec	11	Malm/Rie	2	S	56	Dead	U								16
N. Langen	Dec	11	Malm/Rie	2	S	57			9	2.75	0	0.6875	Y	0	0	5
N. Langen	Dec	11	Malm/Rie	2	S	58			8	2.375	0	0.5625	Y	0	2	37
N. Langen	Dec	11	Malm/Rie	2	S	59			9	2.75	0	0.0625	Y	0	5	19.7
N. Langen	Dec	11	Malm/Rie	2	S	60			11	3.25	0	0.75	Y	0	0	15.7
N. Langen	March	14	Koelenhof	1	S	11			4	0.6	0	0.3	Y	0	4	0.71
N. Langen	March	14	Koelenhof	1	S	12			5	0.5	0	0.2	Y	0	7.5	16.06
N. Langen	March	14	Koelenhof	1	S	13			7	1.9	0	0.2	Y	0	18	0.38
N. Langen	March	14	Koelenhof	1	S	14			4	1.6	0	0.3	Y	0	12.5	1.55
N. Langen	March	14	Koelenhof	1	S	16			NA	1.3	0	0.5	Y	0	13	2
N. Langen	March	14	Koelenhof	1	S	17			1	0.35	0	0.3	Y	0	10	0.71
N. Langen	March	14	Koelenhof	1	S	18			7	0.9	0	0.3	Y	0	13.5	6.4
N. Langen	March	14	Koelenhof	1	S	20			4	1.1	0	0.9	Y	0	12	2.61
N. Langen	March	14	Koelenhof	1	S	21			10	0.6	0	0.3	Y	0	18.5	1.57
N. Langen	March	14	Koelenhof	1	S	23			7	2.5	0	0.9	Y	0	12	0.69
N. Langen	March	14	Koelenhof	1	S	25			NA	NA	NA	NA	N	0	5	0.47
N. Langen	March	14	Koelenhof	1	S	28			4	1.3	0	0.5	Y	0	8	3.36
N. Langen	March	14	Koelenhof	1	S	30			6	0.7	0	0.2	Y	0	21.5	1.87
N. Langen	March	14	Koelenhof	1	S	31			8	0.9	0	0.3	Y	0	18	1.34
N. Langen	March	14	Koelenhof	1	S	32			2	0.8	0	0.5	Y	0	0	3.41
N. Langen	March	14	Koelenhof	1	S	34			6	1.3	0	0.6	Y	0	28	6.83
N. Langen	March	14	Koelenhof	1	S	35			6	1	0	0.5	Y	0	16.5	1.47
N. Langen	March	14	Koelenhof	1	S	36			4	0.8	0	0.7	Y	0	8	1.93
N. Langen	March	14	Koelenhof	1	S	37			9	2	0	1	Y	0	24.5	1.7
N. Langen	March	14	Koelenhof	1	S	38			10	1.8	0	0.5	Y	0	31	2.66
N.Langen	March	14	Klapmuts	1	S	1			6	1.3	0	0.6	Y	0	0	4.6
N.Langen	March	14	Klapmuts	1	S	2			8	1.4	0	1.6	Y	0	4.5	2.94
N.Langen	March	14	Klapmuts	1	S	3			6	1.4	0	0.4	Y	0	4.5	2
N.Langen	March	14	Klapmuts	1	S	5			5	0.4	0	0.2	Y	0	0	6.19
N.Langen	March	14	Klapmuts	1	S	7			6	1.1	0	0.6	Y	0	0	1.5
N.Langen	March	14	Klapmuts	1	S	15			5	1.8	0	0.1	Y	0	13	7.88
N.Langen	March	14	Klapmuts	1	S	19			6	0.8	0	1.5	Y	0	7	0.14
N.Langen	March	14	Klapmuts	1	S	22			8	1.5	0	0.7	Y	0	8	0.9
N.Langen	March	14	Klapmuts	1	S	61			8	0.9	0	0.2	Y	0	13	10.24
N.Langen	March	14	Klapmuts	1	S	64			5	0.9	0	0.3	Y	0	3	1.5
N.Langen	March	14	Klapmuts	1	S	67			0.5	0.4	0	0.2	Y	0	0	1.43
N.Langen	March	14	Klapmuts	1	S	68			8	2.1	0	0.7	Y	0	15	1.12
N.Langen	March	14	Klapmuts	1	S	69			5	1.4	0	0.3	Y	0	14	0.37
N.Langen	March	14	Wor/Slang	2	S	33			8	4.1	0.2	1.1	Y	0	6	0.35
N.Langen	March	14	Wor/Slang	2	S	39			9	3.3	0.3	1.2	Y	0	10	1.02
N.Langen	March	14	Wor/Slang	2	S	63			4	1.9	0	0.4	Y	2	2.5	7.85
N.Langen	March	14	Wor/Slang	2	S	70			4	1.6	0	0.5	Y	0	14	2.67
N.Langen	March	14	Olifantsberg	3	S	24			7	3	0.1	1.1	Y	0	10.5	2.32
N.Langen	March	14	Olifantsberg	3	S	26			6	2	0	0.6	Y	0	13	3.3
N.Langen	March	14	Olifantsberg	3	S	27			7	2.4	0	0.6	Y	0	20	4.2
N.Langen	March	14	Olifantsberg	3	S	29			6	1.7	0	0.6	Y	0	7	2.37

N.Langen	March	14	Olifantsberg	3	S	65			4	2	0	0.9	Y	0	9	4.67
N.Langen	March	14	Malm/Rie	2	S	41			7	0.3	0	0.2	Y	0	9.5	12.54
N.Langen	March	14	Malm/Rie	2	S	42			2	0.3	0	0	Y	0	0	4.9
N.Langen	March	14	Malm/Rie	2	S	43			4	0.6	0	0.2	Y	0	7	2.4
N.Langen	March	14	Malm/Rie	2	S	45			8	1	0	0.2	NA	0	12	9.8
N.Langen	March	14	Malm/Rie	2	S	48			6	0.8	0	0.1	Y	0	8.5	7.2
N.Langen	March	14	Malm/Rie	2	S	49			7	0.2	0	0.1	Y	0	10.5	16.3
N.Langen	March	14	Malm/Rie	2	S	50			5	0.5	0	0.2	Y	0	10.5	9.4
N.Langen	March	14	Malm/Rie	2	S	51			7	0.3	0	0.3	Y	0	15.5	12.72
N.Langen	March	14	Malm/Rie	2	S	52			3	0.2	0	0.1	Y	0	10.5	8
N.Langen	March	14	Malm/Rie	2	S	53			6	1	0	0.4	Y	0	23.5	10
N.Langen	March	14	Malm/Rie	2	S	54			2	0	0	0	Y	0	17.5	11.3
N.Langen	March	14	Malm/Rie	2	S	57			3	0.7	0	0.1	Y	0	8	4.8
N.Langen	March	14	Malm/Rie	2	S	58			NA	0.2	0	0.1	Y	0	6	5.8
N.Langen	March	14	Malm/Rie	2	S	59			NA	0.3	0	0	NA	0	8	7.8
N.Langen	March	14	Malm/Rie	2	S	60	Dead	U								
N.Langen	July	18	Klapmuts	1	S	1			7	0.7	0	0.1	Y	0	0	10.2
N.Langen	July	18	Klapmuts	1	S	2			6	1.1	0	0.2	Y	0	0	4.57
N.Langen	July	18	Klapmuts	1	S	3	Dead	U								
N.Langen	July	18	Klapmuts	1	S	5			4	0.2	0	0.1	Y	0	0	12
N.Langen	July	18	Klapmuts	1	S	7			4	0.8	0	0	Y	0	0	1.67
N.Langen	July	18	Klapmuts	1	S	15			2	0.4	0	0	Y	0	0	18.5
N.Langen	July	18	Klapmuts	1	S	19			8	1.2	0	0.2	Y	0	0	3
N.Langen	July	18	Klapmuts	1	S	22			7	1.9	0	0	Y	0	0	3.67
N.Langen	July	18	Klapmuts	1	S	61			4	0.7	0	0.2	Y	0	0	8.56
N.Langen	July	18	Klapmuts	1	S	67	Dead	U								
N.Langen	July	18	Klapmuts	1	S	68			5	2.4	0	0.3	Y	0	0	2.4
N.Langen	July	18	Klapmuts	1	S	69			7	0.8	0	0.2	Y	0	0	1.33
N.Langen	July	18	Koelenhof	1	S	17	Dead	U								
N.Langen	July	18	Koelenhof	1	S	20	Dead	U								
N.Langen	July	18	Koelenhof	1	S	25	Dead	U								
N.Langen	July	18	Koelenhof	1	S	32	Dead	U								
N.Langen	July	18	Koelenhof	1	S	36	Dead	U								
N.Langen	July	18	Malm/Rie	2	S	11			3	0.6	0	0	Y	0	0	3
N.Langen	July	18	Malm/Rie	2	S	12			1	0.1	0.1	0	Y	0	0	21.5
N.Langen	July	18	Malm/Rie	2	S	13			3	0.8	0	0.1	Y	0	0	2.6
N.Langen	July	18	Malm/Rie	2	S	14			5	0.2	0	0.1	Y	0	0	11
N.Langen	July	18	Malm/Rie	2	S	16			4	0.5	0	0.1	Y	0	0	6.83
N.Langen	July	18	Malm/Rie	2	S	18	Dead	U								
N.Langen	July	18	Malm/Rie	2	S	21			3	0.6	0	0.2	Y	0	0	6.4
N.Langen	July	18	Malm/Rie	2	S	23			1	0.3	0	0	Y	0	0	2.67
N.Langen	July	18	Malm/Rie	2	S	24			.	3.1	0	0.4	Y	0	0	1.16
N.Langen	July	18	Malm/Rie	2	S	26			5	1.4	0	0.1	Y	0	0	6.4
N.Langen	July	18	Malm/Rie	2	S	27			4	1.6	0	0.5	Y	0	0	4.4
N.Langen	July	18	Malm/Rie	2	S	28			5	0.2	0	0.1	Y	0	0	4.68
N.Langen	July	18	Malm/Rie	2	S	29			7	1.2	0	0.1	Y	0	0	1.2
N.Langen	July	18	Malm/Rie	2	S	30			4	0.5	0	0.1	Y	0	0	5.4
N.Langen	July	18	Malm/Rie	2	S	31			2	0.1	0	0	Y	0	0	5.67
N.Langen	July	18	Malm/Rie	2	S	33			8	2.5	0	0.3	Y	0	0	1
N.Langen	July	18	Malm/Rie	2	S	34			3	0.2	0	0.2	Y	0	0	7.67
N.Langen	July	18	Malm/Rie	2	S	37			4	0.9	0	0.1	Y	0	0	3.8
N.Langen	July	18	Malm/Rie	2	S	38			5	0.5	0	0.1	Y	0	0	7.6

N.Langen	July	18	Malm/Rie	2	S	39			8	1.2	0	0.5	Y	0	0	2
N.Langen	July	18	Malm/Rie	2	S	41			3	0	0	0.3	N	0	0	10.5
N.Langen	July	18	Malm/Rie	2	S	42			0.5	0.2	0	0.2	N	0	0	NA
N.Langen	July	18	Malm/Rie	2	S	43			2	0.4	0	0.1	Y	0	0	3.63
N.Langen	July	18	Malm/Rie	2	S	45			3	0.6	0	0.2	Y	0	0	8
N.Langen	July	18	Malm/Rie	2	S	48			1	0.2	0	0	Y	0	0	15.25
N.Langen	July	18	Malm/Rie	2	S	49	Dead	U								
N.Langen	July	18	Malm/Rie	2	S	50			3	0.2	0	0.1	Y	0	0	10.75
N.Langen	July	18	Malm/Rie	2	S	51			3	0.6	0	0.1	Y	0	0	8.89
N.Langen	July	18	Malm/Rie	2	S	52			2	1.1	0	0.5	Y	0	0	4.36
N.Langen	July	18	Malm/Rie	2	S	53			3	1.1	0	0.2	Y	0	0	8.4
N.Langen	July	18	Malm/Rie	2	S	54			2	0.5	0	0.1	Y	0	0	7.8
N.Langen	July	18	Malm/Rie	2	S	57			3	1	0	0.1	Y	0	0	NA
N.Langen	July	18	Malm/Rie	2	S	58	Dead	U								
N.Langen	July	18	Malm/Rie	2	S	59			2	0.6	0	0.2	Y	0	0	9.11
N.Langen	July	18	Malm/Rie	2	S	60			3	0.9	0	0.1	Y	0	0	1.33
N.Langen	July	18	Malm/Rie	2	S	63			3	0.6	0	0.1	Y	0	0	5.8
N.Langen	July	18	Malm/Rie	2	S	64	Dead	U								
N.Langen	July	18	Malm/Rie	2	S	65			4	0.7	0	0.1	Y	0	0	1
N.Langen	July	18	Malm/Rie	2	S	70			4	0.5	0	0.2	Y	0	0	9.2
J van Zyl	May	0	Kogelbaai	2	S	1			13	3	0	1	Y	0	0	0.5
J van Zyl	May	0	Kogelbaai	2	S	2			15	2.5	0	2	Y	0	0	1.3
J van Zyl	May	0	Kogelbaai	2	S	3			15	2	0	2	Y	0	0	11.5
J van Zyl	May	0	Kogelbaai	2	S	4			10	1.5	0	2	Y	0	0	1
J van Zyl	May	0	Kogelbaai	2	S	5			6	2.5	0	2	Y	0	0	4
J van Zyl	May	0	Kogelbaai	2	S	6			8	4.5	0	0.5	Y	0	0	0
J van Zyl	May	0	Kogelbaai	2	S	7			7	2.5	0	1	Y	0	0	0
J van Zyl	May	0	Kogelbaai	2	S	8			7	3.25	0	0	Y	0	0	3
J van Zyl	May	0	Kogelbaai	2	S	9			7	4	0	3	Y	0	0	5.2
J van Zyl	May	0	Kogelbaai	2	S	10			10	4	0	1	Y	0	0	1.5
J van Zyl	May	0	Kogelbaai	2	S	11			8	2	0	3.5	Y	0	0	0
J van Zyl	May	0	Kogelbaai	2	S	12			10	3	0	2	Y	0	0	4.5
J van Zyl	May	0	Kogelbaai	2	S	13			8	.	0	1	Y	0	0	3.5
J van Zyl	May	0	Kogelbaai	2	S	14			6	3	0	2	Y	0	0	10
J van Zyl	May	0	Kogelbaai	2	S	15			5	2	0	2	Y	0	0	1.3
J van Zyl	May	0	Kogelbaai	2	S	16			10	5	0	3	Y	0	0	2
J van Zyl	May	0	Kogelbaai	2	S	17			6	3	0	1	Y	0	0	1.3
J van Zyl	May	0	Kogelbaai	2	S	18			10	4	0	0	Y	0	0	1.2
J van Zyl	May	0	Kogelbaai	2	S	19			13.5	4.5	0	0	Y	0	0	6
J van Zyl	May	0	Kogelbaai	2	S	20			12.5	4	0	0	Y	0	0	0.5
C. McNair	Feb	0	D/ville	6	S	828			10	2.075	1.875	0	Y	0	3.5	1
C. McNair	Feb	0	D/ville	6	S	845			10	4.125	0	0	Y	0	2.65	0.5
C. McNair	Feb	0	D/ville	6	S	846			10	3.55	0	0.7	Y	0	4.5	2
C. McNair	Feb	0	D/ville	6	S	848			10	2.725	0.75	2.08	Y	0	4.865	1.3
C. McNair	Feb	0	D/ville	6	S	850			10	2.625	0.375	0.5	Y	0	1.25	2.5
C. McNair	Feb	0	D/ville	6	S	859			10	3.175	1.5	1.025	Y	0	4.475	2
C. McNair	May	3	D/ville	6	S	853			8	2	0	1.125	Y	0	0	4.4
C. McNair	May	3	D/ville	6	S	858			10	1.75	0.0625	1.3125	Y	1	0	16.5
C. McNair	May	3	D/ville	6	S	204			6	0.8125	0	0.5625	Y	0	0	10.9
C. McNair	May	3	D/ville	6	S	219			5	0.1875	0	0	Y	0	0	1.2

C. McNair	May	3	D/ville	6	S	302			10	0.0625	0	0.125	Y	0	.	26
C. McNair	May	3	D/ville	6	S	650			10	2.3125	0.25	0.625	Y	0	0	2.7
C. McNair	May	3	D/ville	6	S	828			10	2.1875	0.375	1.625	Y	0	0	2.8
C. McNair	May	3	D/ville	6	S	834			20	2.875	0.1875	2	Y	0	0	3
C. McNair	May	3	D/ville	6	S	836			10	1.125	0	0.6875	Y	0	0	7.3
C. McNair	May	3	D/ville	6	S	845			11.5	1.625	0	0.875	Y	0	0	2
C. McNair	May	3	D/ville	6	S	846			10	1	0	0.1875	Y	0	0	7.1
C. McNair	May	3	D/ville	6	S	847			7	1.25	0	0.3125	Y	0	0	1.2
C. McNair	May	3	D/ville	6	S	848			12	1.875	0	1.5625	Y	0	0	10
C. McNair	May	3	D/ville	6	S	850			10	0.375	0	0.625	Y	0	0	6.4
C. McNair	May	3	D/ville	6	S	852			10	2.25	0.125	0.6875	Y	0	0	2.6
C. McNair	May	3	D/ville	6	S	854			10.5	2	0	2.6875	Y	0	0	8
C. McNair	May	3	D/ville	6	S	864			6	0.0625	0	0.0625	NA	1	0	5
C. McNair	May	3	D/ville	6	S	900			10	2.75	0.125	0.1813	Y	0	0	0.9
C. McNair	May	3	D/ville	6	S	901			4	1.625	0	0.3125	Y	0	0	2.7
C. McNair	May	3	D/ville	6	S	902			10	2.25	0.125	0.6875	Y	0	0	2.7
C. McNair	May	3	D/ville	6	S	903			12	2.875	0.1875	2	Y	0	0	1.3
C. McNair	May	3	D/ville	6	S	904			8	2.1875	0.375	1.625	Y	0	0	2.7
C. McNair	Sept	7	D/ville	6	S	204			10	4.1875	1.25	1.125	N	0	0	4.8
C. McNair	Sept	7	D/ville	6	S	219			10	3.75	1.25	1.125	N	2	0	2.5
C. McNair	Sept	7	D/ville	6	S	302			10	3.4375	0.875	2.875	N	0	0	3.2
C. McNair	Sept	7	D/ville	6	S	650			8	2	0.75	2	N	0	0	5
C. McNair	Sept	7	D/ville	6	S	828			9	2.375	0.5	2.25	N	0	0	2.3
C. McNair	Sept	7	D/ville	6	S	834			10	2.875	0.75	1.875	N	0	0	8.9
C. McNair	Sept	7	D/ville	6	S	836			10	3.75	1.375	0.625	N	0	0	2.5
C. McNair	Sept	7	D/ville	6	S	845			10	4.5625	1.3125	0.4375	Y	0	0	2.3
C. McNair	Sept	7	D/ville	6	S	846			6	2.5	0.125	0.4375	Y	0	0	0.5
C. McNair	Sept	7	D/ville	6	S	847			9	4.75	0.75	0.3125	Y	0	0	0.5
C. McNair	Sept	7	D/ville	6	S	848			9	3.375	0.875	1.1875	Y	1	0	4
C. McNair	Sept	7	D/ville	6	S	850			10	3.5	1.4375	1	Y	0	0	NA
C. McNair	Sept	7	D/ville	6	S	852			10	5	1	1.625	Y	0	0	1.3
C. McNair	Sept	7	D/ville	6	S	853			10	3.75	1.5	2.625	Y	0	0	NA
C. McNair	Sept	7	D/ville	6	S	854			10	3.5	2.0625	2	Y	2	0	2.7
C. McNair	Sept	7	D/ville	6	S	858			6	1.5	0.25	1	Y	0	0	12
C. McNair	Sept	7	D/ville	6	S	859			9	3	0.5625	2.5	Y	0	0	3.6
C. McNair	Sept	7	D/ville	6	S	864			10	5	1.375	1.375	Y	1	0	3.2
C. McNair	Sept	7	D/ville	6	S	900			9	3.75	1.125	0.3125	Y	0	0	0.7
C. McNair	Sept	7	D/ville	6	S	902			10	2.875	0.75	2	Y	0	0	9.7
C. McNair	Sept	7	D/ville	6	S	903			10	2.875	0.4375	1.625	Y	0	0	3.6
C. McNair	Sept	7	D/ville	6	S	904			6	2.75	0.625	1.5	Y	0	0	1
C. McNair	Jan	11	D/ville	6	S	204			10	1	0	0	Y	0	0	16
C. McNair	Jan	11	D/ville	6	S	219			10	2.25	0	0.5	Y	0	0	2.4
C. McNair	Jan	11	D/ville	6	S	302			10	1.125	0	1.1875	Y	0	0	15.1
C. McNair	Jan	11	D/ville	6	S	836			1	0.0625	0	0	Y	0	0	NA
C. McNair	Jan	11	D/ville	6	S	845			7	1.875	0	0.375	Y	4	0	3.3
C. McNair	Jan	11	D/ville	6	S	847			10	3	0	0.625	Y	2	0	4.5
C. McNair	Jan	11	D/ville	6	S	848			8	2.75	0.25	0.3125	Y	0	0	2.8
C. McNair	Jan	11	D/ville	6	S	852			8	3.0625	0	0.3125	Y	0	0	1.7
C. McNair	Jan	11	D/ville	6	S	853			9	1.625	0	2	Y	1	0	2
C. McNair	Jan	11	D/ville	6	S	854			10	2.6875	0.0625	0.5625	Y	2	0	7.7
C. McNair	Jan	11	D/ville	6	S	858			7	1.625	0	0	Y	0	0	4
C. McNair	Jan	11	D/ville	6	S	859			10	4	0.3125	0.625	Y	2	0	4.5

C. McNair	Jan	11	D/ville	6	S	864			12	0.125	0	0.0625	Y	7	0	12.4
C. McNair	Jan	11	D/ville	6	S	901			10.5	1.4375	0	0.625	Y	0	0	5
C. McNair	Jan	11	D/ville	6	S	902			7	2	0	0.4375	Y	0	0	8.9
C. McNair	Jan	11	D/ville	6	S	903			8	0.75	.	0.3125	Y	0	0	9.6
P. Ransom	June	0	D/ville	6	S	1			9	1.25	0	0.25	Y	0	0	6.8
P. Ransom	June	0	D/ville	6	S	2			6	0.5	0	0.125	Y	0	0	9.5
P. Ransom	June	0	D/ville	6	S	3			5	0	0	0	Y	0	0	9.06
P. Ransom	June	0	D/ville	6	S	4			3.5	0.5	0	0.125	Y	0	0	5.93
P. Ransom	June	0	D/ville	6	S	5			8	0	0	0.125	NA	0	0	12.5
P. Ransom	June	0	D/ville	6	S	6			5	0.5	0	0.25	Y	0	0	12.29
P. Ransom	June	0	D/ville	6	S	7			3	0.125	0	0	Y	0	0	12.12
P. Ransom	June	0	D/ville	6	S	8			8	0.125	0	0.1875	Y	0	0	11.5
P. Ransom	June	0	D/ville	6	S	9			6	0.75	0	0.375	Y	0	0	12.12
P. Ransom	June	0	D/ville	6	S	10			NA	0	0	0	NA	0	0	6.48
P. Ransom	June	0	D/ville	6	S	11			8	0	0	0.25	NA	0	0	6.9
P. Ransom	June	0	D/ville	6	S	12			8	0.75	0	0.375	Y	0	0	17.9
P. Ransom	June	0	D/ville	6	S	13			4	1	0	0.1375	Y	0	0	24.8
P. Ransom	June	0	D/ville	6	S	14			4	0	0	0.25	NA	0	0	2.6
P. Ransom	June	0	D/ville	6	S	15			5	0.25	0	0.125	Y	0	0	6.16
P. Ransom	June	0	D/ville	6	S	16			6	0.25	0	0.25	Y	0	0	15.16
P. Ransom	June	0	D/ville	6	S	17			6	0.75	0	0.375	Y	0	0	7.62
P. Ransom	June	0	D/ville	6	S	18			6	0.125	0	0.25	Y	0	0	10.5
P. Ransom	June	0	D/ville	6	S	19			5	0.75	0	0.25	Y	0	0	11.25
P. Ransom	June	0	D/ville	6	S	20			7	0.25	0	0.25	Y	0	0	3.92
H. Kiessling	June	0	Kleinmond	2	S	1			15	4.5	0.25	0.25	Y	0	0	3.9
H. Kiessling	June	0	Kleinmond	2	S	2			11	2.5	0.25	0.25	Y	0	0	0
H. Kiessling	June	0	Kleinmond	2	S	3			14	2.75	1	0	Y	0	0	0
H. Kiessling	June	0	Kleinmond	2	S	4			15	4	0.5	0	Y	0	0	0.18
H. Kiessling	June	0	Kleinmond	2	S	5			15	5.75	0.75	0.25	Y	0	0	0.28
H. Kiessling	June	0	Kleinmond	2	S	6			15	4.25	0.25	0	Y	0	0	0
H. Kiessling	June	0	Kleinmond	2	S	7			10	4	0.25	0.25	Y	0	0	0.27
H. Kiessling	June	0	Kleinmond	2	S	8			11	4.5	0.25	0.25	Y	0	0	0
H. Kiessling	June	0	Kleinmond	2	S	9			15	5.5	0.75	0.25	Y	0	0	0
H. Kiessling	June	0	Kleinmond	2	S	10			14	2.75	0.25	0	Y	0	0	0.3
H. Kiessling	June	0	Kleinmond	2	S	11			14	2.75	0	0.75	Y	0	0	0
H. Kiessling	June	0	Kleinmond	2	S	12			11	1.25	0	0.5	Y	0	0	0.32
H. Kiessling	June	0	Kleinmond	2	S	13			15	1.25	0	0.75	Y	0	0	1.43
H. Kiessling	June	0	Kleinmond	2	S	14			14	1.5	0	0.5	Y	0	0	0.25
H. Kiessling	June	0	Kleinmond	2	S	15			14	3	0	0.25	Y	0	0	0.24
H. Kiessling	June	0	Kleinmond	2	S	16			10.5	2.5	0	0.25	Y	0	0	0
H. Kiessling	June	0	Kleinmond	2	S	17			15	3	0.25	0.25	Y	0	0	0.8
H. Kiessling	June	0	Kleinmond	2	S	18			15	4.75	0.5	0	Y	0	0	0
H. Kiessling	June	0	Kleinmond	2	S	19			15	4	0.5	1.25	Y	0	0	0.23
H. Kiessling	June	0	Kleinmond	2	S	20			15	4.25	0.25	0	Y	0	0	0.16
M. Kotze	May	0	Hermanus	4	S	1			8	4	0	2	Y	0	0	0
M. Kotze	May	0	Hermanus	4	S	2			15	4.5	0	1.5	Y	0	0	0.6
M. Kotze	May	0	Hermanus	4	S	3			10	1	0	2	Y	0	0	0
M. Kotze	May	0	Hermanus	4	S	4			10	5	0	1	Y	0	0	0
M. Kotze	May	0	Hermanus	4	S	5			12.5	4	0	0.5	Y	0	0	0

M. Kotze	May	0	Hermanus	4	S	6			15	3	0	3	Y	0	0	1
M. Kotze	May	0	Hermanus	4	S	7			10	3.5	0	2	Y	0	0	14.5
M. Kotze	May	0	Hermanus	4	S	8			15	3	0	3	Y	0	0	0
M. Kotze	May	0	Hermanus	4	S	9			15	5	0	0	Y	0	0	0
M. Kotze	May	0	Hermanus	4	S	10			15	2.5	0	0	Y	0	0	0
M. Kotze	May	0	Hermanus	4	S	11			12.5	2.5	0	2	Y	0	0	0
M. Kotze	May	0	Hermanus	4	S	12			15	3.5	0	4	Y	0	0	0
M. Kotze	May	0	Hermanus	4	S	13			15	2.25	0	2	Y	0	0	0.6
M. Kotze	May	0	Hermanus	4	S	14			15	3.5	0	3	Y	0	0	7
M. Kotze	May	0	Hermanus	4	S	15			15	3.5	0	2	Y	0	0	2
M. Kotze	May	0	Hermanus	4	S	16			14	4	0	3	Y	0	0	0
M. Kotze	May	0	Hermanus	4	S	17			15	2.5	0	3	Y	0	0	0
M. Kotze	May	0	Hermanus	4	S	18			10	2	0	2	Y	0	0	4.6
M. Kotze	May	0	Hermanus	4	S	19			20	3	0	1.5	Y	0	0	4
M. Kotze	May	0	Hermanus	4	S	20			15	4	0	3	Y	0	0	0.6
E. Hunter	May	0	Klipheuwel	6	S	1			6	0.125	0	0.125	Y	0	0	8
E. Hunter	May	0	Klipheuwel	6	S	2			12.5	0	0	0.125	NA	0	0	9.5
E. Hunter	May	0	Klipheuwel	6	S	3			14	0	0	1.4375	NA	0	0	4
E. Hunter	May	0	Klipheuwel	6	S	4			14	0	0	0.1875	NA	0	0	8.5
E. Hunter	May	0	Klipheuwel	6	S	5			9.5	0.25	0	0.375	Y	0	0	16.5
E. Hunter	May	0	Klipheuwel	6	S	6			15	0.5	0	0	Y	0	0	9
E. Hunter	May	0	Klipheuwel	6	S	7			9	0.25	0	0.125	Y	0	0	6.7
E. Hunter	May	0	Klipheuwel	6	S	8			8	0	0.3125	0.1875	Y	0	0	5.3
E. Hunter	May	0	Klipheuwel	6	S	9			10	0.75	0	0.25	Y	0	0	3
E. Hunter	May	0	Klipheuwel	6	S	10			8	0.5	0	0.625	Y	0	0	10
E. Hunter	May	0	Klipheuwel	6	S	11			8	1	0	1.25	Y	0	0	20
E. Hunter	May	0	Klipheuwel	6	S	12			8	1.375	0	0	Y	0	0	11.3
E. Hunter	May	0	Klipheuwel	6	S	13			8	2	0	2.125	Y	0	0	0.7
E. Hunter	May	0	Klipheuwel	6	S	14			10	2.5	0	0.875	Y	0	0	11.3
E. Hunter	May	0	Klipheuwel	6	S	15			11.5	2.75	0	1.8125	Y	0	0	6.4
E. Hunter	May	0	Klipheuwel	6	S	16			6	1.5	0	1.625	Y	0	0	8
E. Hunter	May	0	Klipheuwel	6	S	17			15	3.75	0.25	2.25	Y	0	0	2.7
E. Hunter	May	0	Klipheuwel	6	S	18			10	1.75	0	1.5	Y	0	0	3.3
E. Hunter	May	0	Klipheuwel	6	S	19			6	0.75	0	0.6875	Y	0	0	2.7
E. Hunter	May	0	Klipheuwel	6	S	20			11	0.625	0	1.25	Y	0	0	33
E. Hunter	Jan	8	Klipheuwel	6	S	1	Dead	U								
E. Hunter	Jan	8	Klipheuwel	6	S	2	Dead	U								
E. Hunter	Jan	8	Klipheuwel	6	S	3	Dead	U								
E. Hunter	Jan	8	Klipheuwel	6	S	4	Lost									
E. Hunter	Jan	8	Klipheuwel	6	S	8	Lost									
E. Hunter	Jan	8	Klipheuwel	6	S	11	Dead	U								
E. Hunter	Jan	8	Klipheuwel	6	S	12	Lost									
E. Hunter	Jan	8	Klipheuwel	6	S	16	Lost									
E. Hunter	Jan	8	Klipheuwel	6	S	14			3	2.5625	0	0.375	Y	0	0	5.5
E. Hunter	Jan	8	Joostenberg	6	S	10			10	1.25	0	0.3125	Y	0	0	11
E. Hunter	Jan	8	Joostenberg	6	S	7			8	0.875	0	0.375	Y	0	0	13.3
E. Hunter	Jan	8	D/ville	6	S	17			6	1.375	0	1	Y	0	0	13
E. Hunter	Jan	8	Klipheuwel	6	S	13			8	1.6875	0	0.4375	Y	1	0	1.3
E. Hunter	Jan	8	Klipheuwel	6	S	15			8	1.75	0	0.125	Y	0	0	6
E. Hunter	Jan	8	Klipheuwel	6	S	18	Lost									
E. Hunter	Jan	8	Klipheuwel	6	S	19	Dead	U								

E. Hunter	Jan	8	Klipheuwel	6	S	9			6	2.3125	0.125	1.8125	Y	0	0	1.5
E. Hunter	Jan	8	Klipheuwel	6	S	6			6	1.5	0	1.0625	NA	1	0	1.5
E. Hunter	Jan	8	Klipheuwel	6	S	5			9	2.5	0	0.625	NA	0	0	3
E. Hunter	Jan	8	Klipheuwel	6	S	20			6	0.75	0	0.25	Y	0	0	5
G. Hill	April	0	Helderberg	2	S	1			11	1.625	0	1.125	Y	0	4.5	0.8
G. Hill	April	0	Helderberg	2	S	2			6.5	1.375	0	0	Y	2	0	0.2
G. Hill	April	0	Helderberg	2	S	3			10	4	0.375	0.375	Y	0	0	0.6
G. Hill	April	0	Helderberg	2	S	4			12	2.375	0.25	0.6875	Y	0	0	2.6
G. Hill	April	0	Helderberg	2	S	5			11	2.375	0.125	1.125	Y	0	4.5	2.2
G. Hill	April	0	Helderberg	2	S	6			11.5	3	0.125	1.625	Y	0	0	1.2
G. Hill	April	0	Helderberg	2	S	7			13	1.25	0	1	Y	0	0	0.2
G. Hill	April	0	Helderberg	2	S	8			14.5	3.25	0.25	1.75	Y	0	4.5	0.4
G. Hill	April	0	Helderberg	2	S	9			10.5	2.5	0	0.75	Y	0	0	0.6
G. Hill	April	0	Helderberg	2	S	10			13.5	3.25	0	2.25	Y	0	4.5	0.4
G. Hill	April	0	Helderberg	2	S	11			13	3.75	0.125	0.875	Y	0	0	0
G. Hill	April	0	Helderberg	2	S	12			12	1	0	0.25	Y	0	0	5.4
G. Hill	April	0	Helderberg	2	S	13			10	2.5	0	0.25	Y	0	0	1.6
G. Hill	April	0	Helderberg	2	S	14			11.5	3.375	0	1	Y	0	0	2.6
G. Hill	April	0	Helderberg	2	S	15			11.5	2.75	0.0625	1.5	Y	0	0	0.8
G. Hill	April	0	Helderberg	2	S	16			12.5	3.25	0	1.375	Y	0	4.5	5.6
G. Hill	April	0	Helderberg	2	S	17			14.5	3.125	0	1.375	Y	0	4.5	0.2
G. Hill	April	0	Helderberg	2	S	18			10	2.75	0	0.5	Y	0	0	0
G. Hill	April	0	Helderberg	2	S	19			8	3	0	0.75	Y	0	0	0.2
G. Hill	April	0	Helderberg	2	S	20			9	2.25	0.0625	1.375	Y	0	0	0.2
G. Hill	July	0	Helderberg	2	S	1			9	4.75	0.25	0.5	Y	0	0	1.09
G. Hill	July	3	Helderberg	2	S	2			7	0	0.5	0.375	Y	0	0	4.4
G. Hill	July	3	Helderberg	2	S	3			10	2.75	0.25	0.875	Y	0	0	4.25
G. Hill	July	3	Helderberg	2	S	4			13.5	3	0	0.5	Y	0	3	0.8
G. Hill	July	3	Helderberg	2	S	5			8	0.5	0.25	0.625	Y	0	0	7.25
G. Hill	July	3	Helderberg	2	S	6			10	2.375	0	1.125	Y	0	0	3.5
G. Hill	July	3	Helderberg	2	S	7			8	1.375	0	0.25	Y	0	0	4.75
G. Hill	July	3	Helderberg	2	S	8			10	2.25	0.25	0.25	Y	0	0	0
G. Hill	July	3	Helderberg	2	S	9			5	1	0	0.375	Y	0	0	6
G. Hill	July	3	Helderberg	2	S	10			10	1.25	0	1.75	Y	0	0	5.5
G. Hill	July	3	Helderberg	2	S	11			10	1.625	0	0.75	Y	0	0	4.3
G. Hill	July	3	Helderberg	2	S	12			8	0.75	0	0.5	Y	0	0	NA
G. Hill	July	3	Helderberg	2	S	13			4	0	0	0.125	Y	0	0	8
G. Hill	July	3	Helderberg	2	S	14			10	0.5	0	1.25	Y	0	0	8
G. Hill	July	3	Helderberg	2	S	15			10	2.5	0	1.125	Y	0	0	3.5
G. Hill	July	3	Helderberg	2	S	16			10	1.75	0	3	Y	0	0	11.6
G. Hill	July	3	Helderberg	2	S	17			14.5	0	0	0	Y	0	4.5	NA
G. Hill	July	3	Helderberg	2	S	18			10	3	0.25	1.5	Y	0	0	0.3
G. Hill	July	3	Helderberg	2	S	19			8	NA	0	0.75	Y	0	0	1
G. Hill	July	3	Helderberg	2	S	20			9	2.5	0	1	Y	0	0	0.8
A. Hays	April	0	Kuilsrivier	2	S	1			13.5	2	0	5	Y	1	0	2
A. Hays	April	0	Kuilsrivier	2	S	2			13.5	0.9	0	7	Y	0	0	0.5
A. Hays	April	0	Kuilsrivier	2	S	3			12.5	1.4	0	5	Y	0	0	1.5
A. Hays	April	0	Kuilsrivier	2	S	4			12.5	1.6	0	9	Y	0	0	0.5
A. Hays	April	0	Kuilsrivier	2	S	5			11.5	1.6	0	6	Y	0	0	0
A. Hays	April	0	Kuilsrivier	2	S	6			12.5	2.4	0	6	Y	0	0	1.5

A. Hays	April	0	Kuilsrivier	2	S	7			12.5	1.8	0	5	Y	0	0	0
A. Hays	April	0	Kuilsrivier	2	S	8			11.5	1	0	5	Y	0	0	1
A. Hays	April	0	Kuilsrivier	2	S	9			13.5	1.1	0	3	Y	2	0	4.5
A. Hays	April	0	Kuilsrivier	2	S	10			11	0.7	0	6	Y	0	0	1
A. Hays	April	0	Kuilsrivier	2	S	11			13.5	2	3	4	Y	0	0	5
A. Hays	April	0	Kuilsrivier	2	S	12			12.5	1.5	0	13	Y	0	0	1.5
A. Hays	April	0	Kuilsrivier	2	S	13			13.5	2.5	0	6	Y	0	0	11
A. Hays	April	0	Kuilsrivier	2	S	14			11.5	0.5	0	6	Y	0	0	0
A. Hays	April	0	Kuilsrivier	2	S	15			12.5	2.3	2	3	Y	0	0	1.5
A. Hays	April	0	Kuilsrivier	2	S	16			14.5	1.3	3	4	Y	0	0	1.5
A. Hays	April	0	Kuilsrivier	2	S	17			13	2.1	0	12	Y	0	0	0
A. Hays	April	0	Kuilsrivier	2	S	18			11.2	1.1	0	5	Y	0	0	0
A. Hays	April	0	Kuilsrivier	2	S	19			12	1.6	6	10	Y	0	0	6
A. Hays	April	0	Kuilsrivier	2	S	20			12.5	2	0	4	Y	0	0	0
A. Hays	Jan	9	Klipheuwel	6	S	1			8	4	0	1	Y	0	0	8
A. Hays	Jan	9	Klipheuwel	6	S	2			10	6	1	2	Y	0	9	3.6
A. Hays	Jan	9	Klipheuwel	6	S	3			1	0.5	0	0	N	0	0	0.5
A. Hays	Jan	9	Klipheuwel	6	S	4			6	2	0.5	2	Y	0	0	3.7
A. Hays	Jan	9	Klipheuwel	6	S	5			2	0.75	0	0.5	Y	0	0	1.2
A. Hays	Jan	9	Klipheuwel	6	S	6			5	2	0	0.5	Y	0	0	1.2
A. Hays	Jan	9	Klipheuwel	6	S	7			8	3.25	0.25	0.5	Y	0	0	14.8
A. Hays	Jan	9	Klipheuwel	6	S	8			8	3.25	0	0.5	Y	0	0	0.1
A. Hays	Jan	9	Klipheuwel	6	S	9			5	1.25	0	0.5	Y	0	0	3.5
A. Hays	Jan	9	Klipheuwel	6	S	10			7	3	0.25	0.75	Y	0	0	2.6
A. Hays	Jan	9	Klipheuwel	6	S	11			3	0.5	0	0	Y	0	0	11.3
A. Hays	Jan	9	Klipheuwel	6	S	12			8	3.5	0.25	0.75	Y	0	14	1.2
A. Hays	Jan	9	Klipheuwel	6	S	13			6	2.25	0	0.75	Y	0	0	2.8
A. Hays	Jan	9	Klipheuwel	6	S	14			6	1.75	0	0.5	Y	0	0	0
A. Hays	Jan	9	Klipheuwel	6	S	15			3	1	0	0	Y	0	0	1.8
A. Hays	Jan	9	Klipheuwel	6	S	16			10	5	0.25	0.25	Y	0	10	1.3
A. Hays	Jan	9	Klipheuwel	6	S	17			4	1	0	0.25	Y	0	0	3.5
A. Hays	Jan	9	Klipheuwel	6	S	18			6	2.5	0	0.5	Y	0	0	0.8
A. Hays	Jan	9	Klipheuwel	6	S	19			8	3	0.25	0.5	Y	0	12	3.5
A. Hays	Jan	9	Klipheuwel	6	S	20			8	2	0.5	0.5	Y	0	8	0.8
A. Hays	May	13	Klipheuwel	6	S	1			8	1	0	0.25	Y	0	7	6.4
A. Hays	May	13	Klipheuwel	6	S	2			6	1	0	0	Y	0	3	5.9
A. Hays	May	13	Klipheuwel	6	S	3			5	0.5	0	0	Y	0	0	2.4
A. Hays	May	13	Klipheuwel	6	S	4			7	0.25	0	0	Y	0	9	10.1
A. Hays	May	13	Klipheuwel	6	S	5	Dead	U								
A. Hays	May	13	Klipheuwel	6	S	6			8	0.5	0	0.25	Y	0	9	4.9
A. Hays	May	13	Klipheuwel	6	S	7			5	0	0	0	Y	0	0	4.6
A. Hays	May	13	Klipheuwel	6	S	8			6	0.5	0	0	Y	0	4	16
A. Hays	May	13	Klipheuwel	6	S	9			4	0	0	0	Y	0	0	7.6
A. Hays	May	13	Klipheuwel	6	S	10			7	1	0	0.25	Y	0	9	7.4
A. Hays	May	13	Klipheuwel	6	S	11			3	0.25	0	0	Y	0	0	1.5
A. Hays	May	13	Klipheuwel	6	S	12			9	2	0	0.5	Y	0	18	6.7
A. Hays	May	13	Klipheuwel	6	S	13			7	0.5	0	0	Y	0	0	8.9
A. Hays	May	13	Klipheuwel	6	S	14			6	0.5	0	0	Y	0	0	10.8
A. Hays	May	13	Klipheuwel	6	S	15			3	0	0	0	Y	0	0	3.2
A. Hays	May	13	Klipheuwel	6	S	16			8	2	0.5	0.5	Y	0	9	11
A. Hays	May	13	Klipheuwel	6	S	17			8	3	0	0.5	Y	0	0	7.5
A. Hays	May	13	Klipheuwel	6	S	18			8	1	0	0.5	Y	0	9	1.9

A. Hays	May	13	Klipheuwel	6	S	19			9	2	0	0.5	Y	0	12	12
A. Hays	May	13	Klipheuwel	6	S	20			9	1	0	0.0625	Y	1	7	9
J. Moodie	June	0	Glensheila	5	S	1			13	6.5	0.5	2	Y	0	1.5	1.3
J. Moodie	June	0	Glensheila	5	S	2			13.5	4.5	1	2	Y	0	2.5	2.3
J. Moodie	June	0	Glensheila	5	S	3			12.5	4.5	0	1	Y	0	3.5	2.3
J. Moodie	June	0	Glensheila	5	S	4			10.5	3.5	0.5	1	Y	2	0	1.7
J. Moodie	June	0	Glensheila	5	S	5			7	3	0	1	Y	0	0	1.5
J. Moodie	June	0	Saukloof	5	S	6			14	6.5	0.5	1	Y	0	1.5	0.3
J. Moodie	June	0	Saukloof	5	S	7			14	7	0.5	2	Y	0	2.5	0
J. Moodie	June	0	Saukloof	5	S	8			11.5	7	0	1	Y	0	5	0
J. Moodie	June	0	Saukloof	5	S	9			8	4.5	0	0.5	Y	0	0	0
J. Moodie	June	0	Saukloof	5	S	10			13	7	0	0.5	Y	0	2	0.3
J. Moodie	June	0	Witsands	5	S	11			8.5	5	0	1	Y	0	0	0
J. Moodie	June	0	Witsands	5	S	12			15	8	1.5	0.5	Y	0	1	0.8
J. Moodie	June	0	Witsands	5	S	13			12.5	1	1	3	Y	0	0	0.8
J. Moodie	June	0	Witsands	5	S	14			17.5	7.5	0.5	2	Y	0	2.5	0.6
J. Moodie	June	0	Witsands	5	S	15			17.5	6.5	1	2	Y	0	0	0.8
J. Moodie	June	0	Karoo	1	S	16			8	2.5	0	1	Y	0	0	1.3
J. Moodie	June	0	Karoo	1	S	17			6	1	0	2	Y	0	0	2.3
J. Moodie	June	0	Karoo	1	S	18			10.5	3.5	0	2	Y	0	0	1.1
J. Moodie	June	0	Karoo	1	S	19			5	1	0	1	Y	0	0	1.9
J. Moodie	June	0	Karoo	1	S	20			8	2.5	0	1	Y	0	0	1.8
J. Moodie	Sept	3	Glensheila	5	S	1			8	3	0	0	Y	0	0	5.3
J. Moodie	Sept	3	Glensheila	5	S	2			9	4	0	0	Y	0	0	1.8
J. Moodie	Sept	3	Glensheila	5	S	3	Lost									
J. Moodie	Sept	3	Glensheila	5	S	4			2	1	0	0	Y	0	0	2.9
J. Moodie	Sept	3	Glensheila	5	S	5			6	3	0	0	Y	0	0	3.6
J. Moodie	Sept	3	Glensheila	5	S	6			5	2	0	0	Y	0	0	1.9
J. Moodie	Sept	3	Glensheila	5	S	7			5	3	0.5	0.5	Y	0	0	0.5
J. Moodie	Sept	3	Glensheila	5	S	8			3	0.5	0	0	Y	5	0	0
J. Moodie	Sept	3	Glensheila	5	S	9			7	2	0.5	0.5	Y	0	0	9
J. Moodie	Sept	3	Glensheila	5	S	10			5	2	0	0	Y	0	0	1.9
J. Moodie	Sept	3	Glensheila	5	S	11			5	4	0	0	Y	0	0	2.9
J. Moodie	Sept	3	Glensheila	5	S	12	Lost									
J. Moodie	Sept	3	Glensheila	5	S	13	Lost									
J. Moodie	Sept	3	Glensheila	5	S	14			5	5	0	0	Y	0	0	3
J. Moodie	Sept	3	Glensheila	5	S	15	Lost									
J. Moodie	Sept	3	Glensheila	5	S	16	Lost									
J. Moodie	Sept	3	Glensheila	5	S	17			9	6	0.5	0.5	Y	0	0	5
J. Moodie	Sept	3	Glensheila	5	S	18			9	7	1	1	Y	0	0	0.6
J. Moodie	Sept	3	Glensheila	5	S	19			8	5	0	1	Y	0	0	0.7
J. Moodie	Sept	3	Glensheila	5	S	20			9	6	1	0.5	Y	0	0	4
J. Moodie	May	11	Glensheila	5	S	12			NA	NA	NA	NA	NA	0	0	1.5
J. Moodie	May	11	Glensheila	5	S	14			NA	NA	NA	NA	NA	0	0	2.6
J. Moodie	May	11	Glensheila	5	S	16			NA	NA	NA	NA	NA	0	0	5
J. Moodie	May	11	Glensheila	5	S	17			NA	NA	NA	NA	NA	0	0	1.3
J. Moodie	May	11	Glensheila	5	S	18			NA	NA	NA	NA	NA	0	0	0.25
J. Moodie	May	11	Glensheila	5	S	19			NA	NA	NA	NA	NA	0	0	0.625
J. Lourens	May	0	Muldersvlei	1	S	1			19	2	0	2.0625	Y	0	4.5	4.8
J. Lourens	May	0	Muldersvlei	1	S	2			12.5	2.0625	0	2.1875	Y	0	4.5	6.8

J. Lourens	May	0	Muldersvlei	1	S	3			19	2.375	0	2.1875	Y	0	4.5	17.6
J. Lourens	May	0	Muldersvlei	1	S	4			19	1.75	0	2.125	Y	1	9	10.3
J. Lourens	May	0	Klapmuts	1	S	1			11.5	1.375	0	0.25	Y	1	0	22.25
J. Lourens	May	0	Klapmuts	1	S	2			14.5	0	0	0.6875	Y	0	0	29.4
J. Lourens	May	0	Klapmuts	1	S	3			10.5	1	0	2.125	Y	0	4.5	16
J. Lourens	May	0	Klapmuts	1	S	4			10	2.25	0	1.375	Y	1	9	20.3
J. Lourens	May	0	Klapmuts	1	S	5			13	1.5	0	1.3125	Y	1	9	11.4
J. Lourens	May	0	Klapmuts	1	S	6			18	1.25	0	1	Y	0	9	18
J. Lourens	May	0	Klapmuts	1	S	7			8.5	0.625	0	1.0625	Y	0	8.5	37.6
J. Lourens	May	0	Klapmuts	1	S	8			19	2.25	0	1	Y	0	9	25.3
J. Lourens	May	0	Klapmuts	1	S	11			10	3	0	1.5	Y	0	0	10.3
J. Lourens	May	0	Klapmuts	1	S	12			10	1.25	0	2.125	Y	0	0	35.3
J. Lourens	May	0	Klapmuts	1	S	13			10	1.25	0	0.75	Y	0	9	22.8
J. Lourens	May	0	Klapmuts	1	S	14			10	1.25	0	0.5625	Y	2	9	26.3
J. Lourens	May	0	Simondium	1	S	9			10	1.75	0	1	NA	0	0	15.1
J. Lourens	May	0	Simondium	1	S	10			13	2.25	0	2	Y	0	9	24.5
J. Lourens	May	0	Paarl	1	S	1			10	1	0	0.75	Y	0	9	14.6
J. Lourens	May	0	Paarl	1	S	2			9.5	1	0	1	Y	0	0	16.5
C. Whittol	July	0	Albertina	5	S	1			10	6	1	1	Y	1	1	0
C. Whittol	July	0	Albertina	5	S	2			10	7	0.125	0.5	Y	0	0	0
C. Whittol	July	0	Albertina	5	S	3			10	7	0.5	1	Y	0	1.5	0
C. Whittol	July	0	Albertina	5	S	4			8	5	0.25	1	Y	4	0	0
C. Whittol	July	0	Albertina	5	S	5			8	5	0	0.5	Y	3	0	0
C. Whittol	July	0	Albertina	5	S	7			6	1	0	0.125	Y	0	0	0
C. Whittol	July	0	Albertina	5	S	8			3	0.5	0.5	0.125	Y	0	0	0
C. Whittol	July	0	Lancewood	5	S	11			8	5	0.5	0.5	Y	3	0	1.3
C. Whittol	July	0	Lancewood	5	S	12			7	3	0	0	Y	0	7	0
C. Whittol	July	0	Lancewood	5	S	17			5	2	0	0.5	Y	0	0	0
C. Whittol	July	0	Lancewood	5	S	23			7	3	0.5	0.5	Y	0	0	0
C. Whittol	July	0	Lancewood	5	S	25			7	2	0	0	Y	0	0	0
C. Whittol	July	0	Lancewood	5	S	27			10	1	0	0	Y	0	4	0
C. Whittol	July	0	Albertina	5	S	31			8	5	0.5	1	Y	0	0	0
C. Whittol	July	0	Albertina	5	S	32			6	4	0.5	0.5	Y	0	0	0
C. Whittol	July	0	Albertina	5	S	33			7	4	0.125	0.125	Y	0	0	0
C. Whittol	July	0	Albertina	5	S	34			5	4	0	1	Y	0	0	0
C. Whittol	July	0	Albertina	5	S	41			6	2	0	0.5	Y	0	0	0
C. Whittol	July	0	Albertina	5	S	43			4	2	0	0.5	Y	0	0	0
C. Whittol	July	0	Albertina	5	S	44			6	3	0.125	1	Y	0	1	0
C. Whittol	July	0	Albertina	5	S	45			7	3	0.25	1	Y	0	0	0
C. Whittol	July	0	Albertina	5	S	51			6	3	0	0	Y	0	0	0
C. Whittol	July	0	Albertina	5	S	62			8	5	0.5	1	Y	2	0	0
C. Whittol	July	0	Albertina	5	S	64			6	2	0	0	Y	0	0	0
C. Whittol	July	0	Albertina	5	S	75			9	6	1	1	Y	1	0	0
C. Whittol	July	0	Albertina	5	S	80			10	7	0.5	1	Y	0	1.5	0
C. Whittol	July	0	Lancewood	5	S	107			10	6	0.5	1	Y	0	2	2
C. Whittol	July	0	Lancewood	5	S	112			7	4	0.5	1	Y	0	0	0.6
C. Whittol	July	0	Lancewood	5	S	119			9	4	0.5	1	Y	0	0	0.4
C. Whittol	July	0	Lancewood	5	S	125			10	6	1	1	Y	0	2	0
D. Hugo	May	0	Hopefield	3	S	1			10	1.375	0	0.75	Y	1	4	14.4
D. Hugo	May	0	Hopefield	3	S	2			8	0.5	0	0.25	Y	1	4	1.4

D. Hugo	May	0	Hopefield	3	S	3			10	1.75	0	0.8125	Y	1	10	6.4
D. Hugo	May	0	Hopefield	3	S	4			10	1.375	0	0.5	Y	1	5	2.2
D. Hugo	May	0	Hopefield	3	S	5			7	0.75	0	0.375	Y	1	0	1.7
D. Hugo	May	0	Hopefield	3	S	6			7	0.75	0	0.5625	Y	1	0	1.4
D. Hugo	May	0	Hopefield	3	S	7			10	1.25	0	0.625	Y	1	5	0
D. Hugo	May	0	Hopefield	3	S	8			10	1.25	0	0.5	Y	1	5	2.7
D. Hugo	May	0	Hopefield	3	S	9			10	1.125	0	0.5	Y	1	5	0
D. Hugo	May	0	Hopefield	3	S	10			9	0.875	0	0.5	Y	1	2.5	1.7
D. Hugo	May	0	Hopefield	3	S	11			8	0.5	0	0.375	Y	1	4	13.3
D. Hugo	May	0	Hopefield	3	S	12			6	0.375	0	0.1875	Y	1	0	6.7
D. Hugo	May	0	Hopefield	3	S	13			8	0.625	0	0.375	Y	1	3	9.3
D. Hugo	May	0	Hopefield	3	S	14			8	0.75	0	0.3125	Y	1	3	1
D. Hugo	May	0	Hopefield	3	S	15			10	1	0	0.875	Y	1	10	2.8
D. Hugo	May	0	Hopefield	3	S	16			10	1.5	0	0.6875	Y	1	10	4
D. Hugo	May	0	Hopefield	3	S	17			7	0.75	0	0.625	Y	1	0	0.8
D. Hugo	May	0	Hopefield	3	S	18			10	1	0	0.3125	Y	1	8	1
D. Hugo	May	0	Hopefield	3	S	19			10	1	0	0.5	Y	1	12.5	13.3
D. Hugo	May	0	Hopefield	3	S	20			10	1.375	0	0.4375	Y	1	10	0
D. Hugo	Sept	4	Malm/Darl	3	S	1			7	5	0.0625	1.5	Y	4	0	27.4
D. Hugo	Sept	4	Malm/Darl	3	S	2			8	5	0.125	2.5	Y	1	0	6
D. Hugo	Sept	4	Malm/Darl	3	S	3			7	4	0.125	2	Y	0	0	1
D. Hugo	Sept	4	Malm/Darl	3	S	4			12	7	0.125	2.5	Y	1	0	4.7
D. Hugo	Sept	4	Malm/Darl	3	S	5			12	7	0.125	2.5	Y	1	0	14.3
D. Hugo	Sept	4	Malm/Darl	3	S	6			8	4	0.125	1.5	Y	2	0	6.5
D. Hugo	Sept	4	Malm/Darl	3	S	7			12	8	0.25	1	Y	1	0	1.3
D. Hugo	Sept	4	Malm/Darl	3	S	8			15	9	0.5	1	Y	1	0	1.7
D. Hugo	Sept	4	Malm/Darl	3	S	9			12.5	8.5	0.5	1.5	Y	2	0	2
D. Hugo	Sept	4	Malm/Darl	3	S	10			12	8	0.5	1.5	Y	1	0	1.4
D. Hugo	Sept	4	Hopefield	3	S	11			11	7	0.25	2	Y	1	0	1.7
D. Hugo	Sept	4	Hopefield	3	S	12			10.5	6	0.125	2	Y	1	0	6.2
D. Hugo	Sept	4	Hopefield	3	S	13			12	8	0.25	2.5	Y	1	0	0.9
D. Hugo	Sept	4	Hopefield	3	S	14			6	2	0.0625	0.5	Y	0	0	2.6
D. Hugo	Sept	4	Hopefield	3	S	15			11.5	8	0.125	2	Y	3	0	1.4
D. Hugo	Sept	4	Hopefield	3	S	16			14	8.5	0.5	1.5	Y	1	0	8.4
D. Hugo	Sept	4	Hopefield	3	S	17			12.5	9	0.25	1	Y	2	0	1.3
D. Hugo	Sept	4	Hopefield	3	S	18			14	8.5	0.5	2	Y	3	0	17.1
D. Hugo	Sept	4	Hopefield	3	S	19			13	8.5	0.25	2	Y	0	0	12.8
D. Hugo	Feb	9	Hopefield	3	S	20			6	5	0.0625	1.5	Y	0	0	1.7
D. Hugo	Feb	9	Hopefield	3	S	1			4	1	0	0.25	NA	0	0	4.5
D. Hugo	Feb	9	Hopefield	3	S	2	Dead	R								
D. Hugo	Feb	9	Hopefield	3	S	3			8	4	0.125	2	NA	0	8	4
D. Hugo	Feb	9	Hopefield	3	S	4	Dead	R								
D. Hugo	Feb	9	Hopefield	3	S	5			4	1	0	1	NA	0	0	18
D. Hugo	Feb	9	Hopefield	3	S	6			4	0.75	0	1	NA	0	0	5
D. Hugo	Feb	9	Hopefield	3	S	7	Dead	F								
D. Hugo	Feb	9	Hopefield	3	S	8	Dead	F								
D. Hugo	Feb	9	Hopefield	3	S	9	Dead	F								
D. Hugo	Feb	9	Hopefield	3	S	10	Dead	F								
D. Hugo	Feb	9	Hopefield	3	S	11			8.5	6	0	2	Y	0	7	5.4
D. Hugo	Feb	9	Hopefield	3	S	12			6.5	3	0	2	Y	0	9	4.5
D. Hugo	Feb	9	Hopefield	3	S	13			9	5	0.25	2	NA	0	3	0.5
D. Hugo	Feb	9	Hopefield	3	S	14	Dead	F								

D. Hugo	Feb	9	Hopefield	3	S	15	Dead	F								
D. Hugo	Feb	9	Hopefield	3	S	16			8.5	4	0	1.5	Y	0	4	5
D. Hugo	Feb	9	Hopefield	3	S	17			8.5	4	0	2	Y	0	5	4.7
D. Hugo	Feb	9	Hopefield	3	S	18	Dead	U								
D. Hugo	Feb	9	Hopefield	3	S	19			11	6	0	4	Y	0	9	7
D. Hugo	Feb	9	Hopefield	3	S	20			11.5	6	0.25	3	Y	0	11	3.9
D. Hugo	June	13	Hopefield	3	S	1			2.5	1	0.083	0.75	Y	0	0	1
D. Hugo	June	13	Hopefield	3	S	3			2.5	1	0.083	0.75	Y	0	0	3
D. Hugo	June	13	Hopefield	3	S	5			2.5	0.75	0	0.75	Y	0	0	5.33
D. Hugo	June	13	Hopefield	3	S	6			2.5	1	0	0.25	Y	0	0	0
D. Hugo	June	13	Hopefield	3	S	11			5	1	0	0.25	Y	0	0	0
D. Hugo	June	13	Hopefield	3	S	12			3	0.5	0	0.125	Y	0	0	0
D. Hugo	June	13	Hopefield	3	S	13			2	0.5	0	0.125	Y	0	0	0
D. Hugo	June	13	Hopefield	3	S	16			2	1	0	0.25	Y	0	0	9
D. Hugo	June	13	Hopefield	3	S	17			3.5	1.5	0	0.5	Y	0	0	0
D. Hugo	June	13	Hopefield	3	S	19			3	1.5	0	0.5	Y	0	0	6
D. Hugo	June	13	Hopefield	3	S	20			4	2	0	0.75	Y	0	0	6
D. Hugo	Oct	17	Hopefield	3	S	1			7	3	0	1	Y	0	0	0
D. Hugo	Oct	17	Hopefield	3	S	3			11.5	6	0.125	2	Y	0	0	0
D. Hugo	Oct	17	Hopefield	3	S	5			12.5	8	0.25	2	Y	1	5	0
D. Hugo	Oct	17	Hopefield	3	S	6			12	3	0.5	2.5	Y	1	4	0
D. Hugo	Oct	17	Hopefield	3	S	11			15	8	0.25	2	Y	2	5	4.62
D. Hugo	Oct	17	Hopefield	3	S	12			13	8	0.25	2	Y	1	6	0
D. Hugo	Oct	17	Hopefield	3	S	13			10	7	0.25	2	Y	1	0	0.37
D. Hugo	Oct	17	Hopefield	3	S	16			8	5	0	2	Y	0	0	0.71
D. Hugo	Oct	17	Hopefield	3	S	17			8	6	0.125	1.5	Y	0	0	0
D. Hugo	Oct	17	Hopefield	3	S	19			15	8	0.5	1.5	Y	1	10	0
D. Hugo	Oct	17	Hopefield	3	S	20			15	8	0.5	1.5	Y	2	10	0.59

APPENDIX IV:
POPULATION DYNAMICS

STELLENBOSCH

ACTION	DETAILS	NOTES
Introduce 15x "newly-trapped" (<6 months) colonies into raised boxes, on stands, with varroa screens. Prevent access to ants.	10/03/01	15 boxes in Stellenbosch
Sample colonies for varroa mites	28/03/01 Col 1 10 mites in 453 bees Col 2 2/403 Col 3 1/414 Col 4 0/420 Col 5 6/487 Col 6 8/518 Col 7 2/412 Col 9 12/416 Col 10 10/513 Col 11 1/410 Col 12 0/453 Col 13 12/428 Col 14 5/508 Col 15 0/446	
4 Bayvarol strips in each colony	28/03/01	
Bayvarol strips removed from colonies	09/05/01	
Two week waiting period ends	23/05/01	
Demographic and varroa samples on colonies	25/05/01	See Data Sheet
Extra waiting period for varroa screens material to arrive	Until 05/06/01	

Sampling of colonies at Welgevallen belonging to Attie Mostert, for choice of colony as donor colony	05/06/01 Col 6 26 varroa in 415 bees	
Collection of varroa mites from sealed brood frames from Welgevallen colony 6 (all from same colony); introduced 20 mites per colony into the A1-15 colonies, with removal of open brood frame from each colony, and remote to the colony, the placement of 20 mites on each frame; which is then returned to the colony.	08/06/01	
Counting and removal of varroa mites on each varroa screen	22/06/01 Col 1 0 mites Col 2 4 mites Col 3 2 mites Col 4 0 mites Col 5 0 mites Col 6 0 mites Col 7 0 mites Col 8 2 mites Col 9 4 mites Col 10 6 mites Col 11 7 mites Col 12 2 mites Col 13 2 mites Col 14 6 mites Col 15 5 mites	
Demographic data on colonies	22/06/01	See Data Sheet
Counting and removal of varroa mites on each varroa screen	06/07/01 Col 1 2 mites Col 2 Full of Water Col 3 0 mites Col 4 0 mites Col 5 3 mites Col 6 1 mites Col 7 0 mites Col 8 1 mites Col 9 2 mites Col 10 0 mites Col 11 0 mites Col 12 0 mites Col 13 1 mites Col 14 2 mites Col 15 1 mites	

Counting and removal of varroa mites on each varroa screen	20/07/01 Col 1 0 mites Col 2 Full of Water Col 3 3 mites Col 4 5 mites Col 5 2 mites Col 6 1 mite Col 7 1 mite Col 8 2 mites Col 9 0 mites – ants Col 10 0 mites Col 11 0 mites – ants Col 12 0 mites Col 13 0 mites – ants Col 14 0 mites Col 15 Full of water	
Counting and removal of varroa mites on each varroa screen	03/08/01 Col 1 0 mites Col 2 2 mites Col 3 14 mites Col 4 9 mites Col 5 2 mites Col 6 3 mites Col 7 5 mites Col 8 28 mites Col 9 1 mite Col 10 3 mites Col 11 12 mites Col 12 37 mites Col 13 6 mites Col 14 10 mites Col 15 4 mites	
Demographic data on colonies	03/08/01	See Data Sheet
Counting and removal of varroa mites on each varroa screen	17/08/01 Col 1 2 mites Col 2 3 mites Col 3 2 mites Col 4 1 mite Col 5 0 mites Col 6 0 mites – ants Col 7 5 mites Col 8 1 mite Col 9 0 mites – ants Col 10 2 mites Col 11 1 mite Col 12 3 mites Col 13 4 mites Col 14 6 mites Col 15 0 mites	

Demographic data on colonies	31/08/01	See Data Sheet
Counting and removal of varroa mites on each varroa screen	31/08/01 Col 1 2 mites Col 2 0 mites Col 3 3 mites Col 4 1 mite Col 5 0 mites Col 6 0 mites Col 7 0 mites Col 8 2 mites Col 9 0 mites Col 10 2 mites Col 11 0 mites Col 12 0 mites Col 13 0 mites Col 14 2 mites Col 15 1 mite	
Counting and removal of varroa mites on each varroa screen	14/09/01 Col 1 10 mites Col 2 4 mites Col 3 5 mites Col 4 12 mite Col 5 2 mites Col 6 DEAD Col 7 DEAD Col 8 6 mites Col 9 2 mites Col 10 43 mites Col 11 46 mites Col 12 33 mites Col 13 9 mites Col 14 8 mites Col 15 3 mites	Now 7 weeks of almost constant rain in the Cape; taking its toll on the bees. Colonies 6 & 7 dead of hunger; all dead bees in the colonies. All other colonies fed on this day (14/09).
Demographic data on colonies	28/09/01	See Data Sheet
Counting and removal of varroa mites on each varroa screen	28/09/01 Col 1 4 mites Col 2 3 mites Col 3 16 mites Col 4 9 mites Col 5 5 mites Col 6 Empty Col 7 Empty Col 8 38 mites Col 9 5 mites Col 10 38 mites Col 11 8 mites Col 12 18 mites Col 13 32 mites Col 14 12 mites Col 15 8 mites	

Counting and removal of varroa mites on each varroa screen	12/10/01 Col 1 17 mites Col 2 5 mites Col 3 68 mites Col 4 6 mites Col 5 23 mites Col 6 Empty Col 7 Empty Col 8 44 mites Col 9 21 mites Col 10 14 mites Col 11 2 mites – Bees Inside Col 12 16 mites Col 13 49 mites Col 14 18 mites Col 15 18 mites	
Demographic data on colonies	26/10/01	See Data Sheet
Counting and removal of varroa mites on each varroa screen	26/10/01 Col 1 29 mites Col 2 1 mite Col 3 26 mites Col 4 17 mites Col 5 14 mites Col 6 Empty Col 7 Empty Col 8 18 mites Col 9 8 mites Col 10 22 mites Col 11 15 mites Col 12 16 mites Col 13 4 mites Col 14 3 mites Col 15 3 mites	
Counting and removal of varroa mites on each varroa screen	09/11/01 Col 1 9 mites Col 2 Empty Col 3 22 mites Col 4 14 mites Col 5 2 mites Col 6 Empty Col 7 Empty Col 8 13 mites Col 9 3 mites Col 10 16 mites Col 11 2 mites Col 12 2 mites Col 13 1 mites Col 14 1 mites Col 15 3 mites	

Demographic data on colonies	09/11/01	See Data Sheet
Varroa Samples	09/11/01 Col 1: 0 varroa in 312 bees Col 2: 2 empty Col 3: 0 in 279 Col 4: 0 in 352 Col 5: 0 in 278 Col 6: Empty Col 7: Empty Col 8: 0 in 308 Col 9: 1 in 254 Col 10: 1 in 317 Col 11: 1 in 296 Col 12: 0 in 392 Col 13: 0 in 326 Col 14: 0 in 262 Col 15: 1 in 367	
Counting and removal of varroa mites on each varroa screen	07/12/01 Col 1 0 mites Col 2 Empty Col 3 4 mites Col 4 10 mites Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 12 mites Col 9 4 mites Col 10 6 mites Col 11 0 mites Col 12 2 mites Col 13 0 mites Col 14 0 mites Col 15 2 mites	
Counting and removal of varroa mites on each varroa screen	14/01/02 Col 1 2 mites Col 2 Empty Col 3 4 mites Col 4 0 mites Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 0 mites Col 9 0 mites Col 10 0 mites Col 11 0 mites Col 12 1 mites Col 13 0 mites Col 14 0 mites Col 15 0 mites	

Demographic data on colonies	29/01/02	See Data Sheet
Counting and removal of varroa mites on each varroa screen	29/01/02 Col 1 3 mites Col 2 Empty Col 3 14 mites Col 4 1 mite Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 0 mites Col 9 0 mites Col 10 7 mites Col 11 0 mites Col 12 1 mite Col 13 0 mites Col 14 0 mites Col 15 0 mites	
Counting and removal of varroa mites on each varroa screen	11/02/02 Col 1 0 mites Col 2 Empty Col 3 6 mites Col 4 1 mite Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 0 mites Col 9 2 mites Col 10 0 mites Col 11 3 mites Col 12 5 mites Col 13 0 mites Col 14 1 mite Col 15 1 mite	
Demographic data on colonies	25/02/02	See Data Sheet
Counting and removal of varroa mites on each varroa screen	25/02/02 Col 1 1 mite Col 2 Empty Col 3 10 mites Col 4 0 mites Col 5 1 mite Col 6 Empty Col 7 Empty Col 8 0 mites Col 9 1 mite Col 10 0 mites Col 11 0 mites Col 12 0 mites Col 13 0 mites Col 14 0 mites Col 15 0 mites	

Counting and removal of varroa mites on each varroa screen	11/03/02 Col 1 0 mites Col 2 Empty Col 3 1 mite Col 4 0 mites Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 0 mites Col 9 1 mite Col 10 0 mites Col 11 0 mites Col 12 1 mite Col 13 0 mites Col 14 0 mites Col 15 0 mites	
Demographic data on colonies	26/03/02	See Data Sheet
Counting and removal of varroa mites on each varroa screen	26/03/02 Col 1 Empty Col 2 Empty Col 3 4 mites Col 4 3 mites Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 0 mites Col 9 0 mites Col 10 2 mites Col 11 0 mites Col 12 1 mite Col 13 0 mites Col 14 1 mite Col 15 0 mites	
Demographic data on colonies	22/04/02	See Data Sheet
Counting and removal of varroa mites on each varroa screen	22/04/02 Col 1 Empty Col 2 Empty Col 3 0 mites Col 4 0 mites Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 0 mites Col 9 0 mites Col 10 2 mites Col 11 0 mites Col 12 0 mites Col 13 0 mites Col 14 0 mites Col 15 0 mites	

Counting and removal of varroa mites on each varroa screen	06/05/02 Col 1 Empty Col 2 Empty Col 3 1 mite Col 4 2 mites Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 0 mites Col 9 0 mites Col 10 13 mites Col 11 0 mites Col 12 0 mites Col 13 0 mites Col 14 0 mites Col 15 0 mites	
Demographic data on colonies	27/05/02	See Data Sheet
Counting and removal of varroa mites on each varroa screen	27/05/02 Col 1 Empty Col 2 Empty Col 3 21 mites Col 4 9 mites Col 5 3 mites Col 6 Empty Col 7 Empty Col 8 3 mites Col 9 0 mites Col 10 17 mites Col 11 23 mites Col 12 7 mites Col 13 3 mites Col 14 3 mites Col 15 0 mites	
Counting and removal of varroa mites on each varroa screen	10/06/02 Col 1 Empty Col 2 Empty Col 3 6 mites Col 4 1 mite Col 5 2 mites Col 6 Empty Col 7 Empty Col 8 1 mite – Empty Col 9 1 mite Col 10 4 mites Col 11 22 mites Col 12 1 mite Col 13 1 mite Col 14 3 mites Col 15 1 mite	

4 Bayvarol strips in each colony	15/07/02	
Counting and removal of varroa mites on each varroa screen	17/07/02 Col 1 Empty Col 2 Empty Col 3 19 mites Col 4 40 mites Col 5 13 mites Col 6 Empty Col 7 Empty Col 8 Empty Col 9 3 mites Col 10 Empty Col 11 192 mites Col 12 68 mites Col 13 41 mites Col 14 Empty Col 15 Empty	
Counting and removal of varroa mites on each varroa screen	19/07/02 Col 1 Empty Col 2 Empty Col 3 29 mites Col 4 4 mites Col 5 1 mite Col 6 Empty Col 7 Empty Col 8 Empty Col 9 2 mites Col 10 Empty Col 11 46 mites Col 12 15 mites Col 13 5 mites Col 14 Empty Col 15 Empty	
Counting and removal of varroa mites on each varroa screen	22/07/02 Col 1 Empty Col 2 Empty Col 3 18 mites Col 4 4 mites Col 5 6 mites Col 6 Empty Col 7 Empty Col 8 Empty Col 9 2 mites Col 10 Empty Col 11 55 mites Col 12 2 mites Col 13 3 mites Col 14 Empty Col 15 Empty	

Counting and removal of varroa mites on each varroa screen	24/07/02 Col 1 Empty Col 2 Empty Col 3 10 mites Col 4 1 mite Col 5 3 mites Col 6 Empty Col 7 Empty Col 8 Empty Col 9 6 mites Col 10 Empty Col 11 89 mites Col 12 17 mites Col 13 9 mites Col 14 Empty Col 15 Empty	
Counting and removal of varroa mites on each varroa screen	26/07/02 Col 1 Empty Col 2 Empty Col 3 2 mites Col 4 2 mites Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 Empty Col 9 2 mites Col 10 Empty Col 11 5 mites Col 12 13 mites Col 13 1 mite Col 14 Empty Col 15 Empty	
Counting and removal of varroa mites on each varroa screen	29/07/02 Col 1 Empty Col 2 Empty Col 3 3 mites Col 4 1 mite Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 Empty Col 9 1 mite Col 10 Empty Col 11 7 mites Col 12 4 mites Col 13 1 mite Col 14 Empty Col 15 Empty	
2 Apivar strips in each colony	29/07/02	

Counting and removal of varroa mites on each varroa screen	31/07/02 Col 1 Empty Col 2 Empty Col 3 9 mites Col 4 1 mite Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 Empty Col 9 0 mites Col 10 Empty Col 11 4 mites Col 12 0 mites Col 13 1 mite Col 14 Empty Col 15 Empty	
Counting and removal of varroa mites on each varroa screen	02/08/02 Col 1 Empty Col 2 Empty Col 3 9 mites Col 4 2 mites Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 Empty Col 9 0 mites Col 10 Empty Col 11 6 mites Col 12 0 mites Col 13 0 mites Col 14 Empty Col 15 Empty	
Counting and removal of varroa mites on each varroa screen	05/08/02 Col 1 Empty Col 2 Empty Col 3 6 mites Col 4 1 mite Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 Empty Col 9 1 mite Col 10 Empty Col 11 6 mites Col 12 0 mites Col 13 1 mites Col 14 Empty Col 15 Empty	

Counting and removal of varroa mites on each varroa screen	07/08/02 Col 1 Empty Col 2 Empty Col 3 3 mites Col 4 0 mites Col 5 0 mites Col 6 Empty Col 7 Empty Col 8 Empty Col 9 2 mites Col 10 Empty Col 11 4 mites Col 12 0 mites Col 13 0 mites Col 14 Empty Col 15 Empty	
Freezing and full screen of colonies for varroa mite	08/08/02 Col 3 2 mites Col 11 5 mites	

KWAZULU-NATAL

ACTION	DETAILS	NOTES
Introduce 10x "newly-trapped" (<6 months) colonies into raised boxes, on stands, with varroa screens. Prevent access to ants.	14 /06/ 01 Screens etc late in arrival.	15 boxes in Stellenbosch; only 10 in KZN
Sample colonies for varroa mites	11/04/01 ***col no . no mites .no bees*** 1 9 400 2 0 420 3 0 380 4 0 350 5 11 400 6 0 410 7 0 360 8 0 390 9 0 400 10 2 380	
4 Bayvarol strips in each colony	11 /04 /01	
Bayvarol strips removed from colonies	14 /06 /01 Re-hived and inserted screens	Note : demo data, screen Count and varroa sample See data sheet
Two week waiting period ends	28 /06 / 01	Introduced 20 varroa Took 3 days Full data collected before Introducing varroa All counts 0 Aborted colony 3 (capensis)
Demographic and varroa samples on colonies	12 /07 /01	See Data Sheet
Sampling of colonies for choice of colony as donor colony	27/06/01	
Collection of varroa mites from sealed brood frames from donor colony (all from same colony); introduced 20 mites per colony into the A1-10 colonies, with removal of open brood frame from each colony, and remote to the colony, the placement of 20 mites on each frame; which is then returned to the colony.	28 /06 /01 29 /06 /01 30 /06 /01	3 days to achieve satisfactory results r.e. data sheet.

Counting and removal of varroa mites on each varroa screen	12 /07 /01 colony no mite no col 1 5 col 2 3 col 4 11 col 7 2 col 8 2 col 9 4 col 10 0	
Counting and removal of varroa mites on each varroa screen	26/07/01 colony no mite no col 1 6 col 2 3 col 4 4 col 7 2 col 8 3 col 9 8 col10 2	
Counting and removal of varroa mites on each varroa screen	08/08/2001 colony no mite no col 1 7 col 2 16 col 4 28 col 7 9 col 8 17 col 9 33 col 10 7	
Counting and removal of varroa mites on each varroa screen	23/08/2001 colony no mite no col 1 15 col 2 24 col 4 18 col 7 4 col 8 32 col 9 62 col 10 3	
Counting and removal of varroa mites on each screen	06/09/2001 colony no mite no col 1 18 col 2 24 col 4 16 col 7 13 col 8 24 col 9 54 col 10 6	

Counting and removal of varroa Mites on each screen	20/09/2001 colony no mite no col 1 20 col 2 28 col 4 14 col 7 18 col 8 28 col 9 63 col 10 12	
Counting and removal of varroa mites on each screen	04/10/2001 colony no mite no col 1 26 col 2 7 col 4 9 col 7 11 col 8 14 col 9 72 col 10 17	
Counting and removal of varroa from each screen	18/10/2001 colony no mite no col 1 6 col 2 25 col 4 12 col 7 7 col 8 15 col 9 63 col 10 2	
Counting and removal of varroa from each screen	01/11/2001 colony no mite no col 1 16 col 2 17 col 4 12 col 7 9 col 8 4 col 9 24 col 10 7	
Counting and removal of varroa from each screen	15 /11/2001 colony no mite no col 1 22 col 2 9 col 4 18 col 7 13 col 8 9 col 9 36 col 10 14	

Counting and removal of varroa from each screen	30/11/2001 colony no mite no col 1 18 col 2 23 col 4 16 col 7 13 col 8 15 col 9 44 col 10 23	Late due to rain , colony 7 waterlogged due to collapsed stand .?
Counting and removal of varroa from each screen	13 /12/2001 colony no mite no col 1 22 col 2 12 col 4 21 col 7 18 col 8 31 col 9 64 col 10 31	
Counting and removal of varroa from each screen	28/12/2001 colony no mite no col 1 18 col 2 16 col 4 34 col 7 14 col 8 25 col 9 72 col 10 41	
Counting and removal of varroa from each screen	10/01/2002 colony no mite no col 1 26 col 2 28 col 4 39 col 7 24 col 8 31 col 9 65 col 10 54	
Counting and removal of varroa from each screen	24/01/2002 colony no mite no col 1 50 col 2 10 col 4 29 col 7 7 col 8 18 col 9 95 col 10 15	Colony 8 has multiple eggs

Counting and removal of varroa from each screen	07/02/2002 colony no mite no col 1 37 col 2 68 col 4 27 col 7 19 col 8 31 col 9 109 col 10 17	
Counting and removal of varroa from each screen	21/02/2002 colony no mite no col 1 108 col 2 36 col 4 84 col 7 38 col 9 78 col 10 58	See demo data
Counting and removal of varroa from each screen	07/03/2002 colony no mite no col 1 63 col 2 24 col 4 30 col 7 18 col 9 63 col 10 32	
Counting and removal of varroa from each screen	21/03/2002 colony no mite no col 1 30 col 2 48 col 4 62 col 7 42 col 9 64 col 10 22	See demo data
Counting and removal of varroa from each screen	04/04/2002 colony no mite no col 1 140 col 2 no count col 4 196 col 7 2 col 9 213 col 10- 96	Col 2 stand collapsed : Therefore no count

Counting and removal of varroa from each screen	18/04/2002 colony no mite no col 1 176 col 2 70 col 4 292 col 7 195 col 9 175 col 10 260	See demo data
Counting and removal of varroa from each screen	30/05/2002 colony no mite no col 1 64 col 2 640 col 4 1334 col 7 1110 col 9 770 col 10 391	
Counting and removal of varroa from each screen	13/06/2002 colony no mite no col 1 150 col 2 1010 col 4 586 col 7 1200 col 9 338 col 10 920	See demo data
4 Bayvarol strips in each colony	27/07/2002	
Counting and removal of varroa from each screen	31/07/2002 colony no mite no col 1 Dead col 2 147 col 4 Dead col 7 736 col 9 Dead col 10 353	
Counting and removal of varroa from each screen	02/08/2002 colony no mite no col 1 Dead col 2 477 col 4 Dead col 7 597 col 9 Dead col 10 808	

Counting and removal of varroa from each screen	05/08/2002 colony no mite no col 1 Dead col 2 47 col 4 Dead col 7 295 col 9 Dead col 10 159	
Counting and removal of varroa from each screen	08/08/2002 colony no mite no col 1 Dead col 2 7 col 4 Dead col 7 11 col 9 Dead col 10 6	
2 Apivar strips in each colony	08/08/2002	
Counting and removal of varroa from each screen	11/08/2002 colony no mite no col 1 Dead col 2 1 col 4 Dead col 7 2 col 9 Dead col 10 5	
Counting and removal of varroa from each screen	14/08/2002 colony no mite no col 1 Dead col 2 0 col 4 Dead col 7 0 col 9 Dead col 10 0	
Counting and removal of varroa from each screen	08/08/2002 colony no mite no col 1 Dead col 2 0 col 4 Dead col 7 1 col 9 Dead col 10 0	

Varroa Population Dynamics – Stellenbosch Date: 25/05/01

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	9	4	0	1.5	3	Y	0	0	0	0	502	0.0
2	10	4	0.125	3	2.5	Y	0	0	0	0	400	0.0
3	9	3	0	0.75	1.5	Y	0	0	0	0	406	0.0
4	8	3	0	1.5	1	Y	0	1	0	0	354	0.0
5	10	3	0	2	3	Y	0	0	0	0	512	0.0
6	8	3.5	0	2.5	1.5	Y	0	1	0	0	415	0.0
7	8	2.5	0.25	3	2	Y	0	0	0	0	408	0.0
8	10	4.5	0.25	2	2.5	Y	0	0	0	0	427	0.0
9	8	3	0.125	2	2.5	Y	0	0	0	0	310	0.0
10	9	3	0.5	2.5	2.5	Y	0	0	0	0	444	0.0
11	10	4	0.5	3	1	Y	0	0	0	0	501	0.0
12	10	5	0.75	0.5	1	Y	0	1	0	0	398	0.0
13	10 + 5	5.5	0.5	0.25	0.75	Y	0	0	0	0	427	0.0
14	10	6	0.25	1.5	0.75	Y	0	0	0	0	357	0.0
15	6	4	0	0.5	0.25	Y	0	0	0	0	488	0.0

Varroa Population Dynamics – Stellenbosch Date: 22/06/01

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Notes
1	8	4	0.125	0.25	3	Y	0	0	0	
2	10	6	0.5	1	1	Y	0	0	0	
3	10	5	0.125	0.25	2	Y	0	1	0	
4	10	4	0	0.5	1	Y	0	0	0	
5	10	4.5	0.125	0.125	4	Y	0	0	0	
6	10	5	0.125	0.125	3	Y	0	5	0	
7	9	6	0.5	0.25	0.5	Y	0	2	0	
8	10	5.5	0.5	0.5	1	Y	0	0	0	
9	9	4	0.25	1.5	2	Y	1	0	0	
10	10	5	0.5	0.25	1	Y	0	0	0	
11	10	4.75	0.25	2	1	Y	0	0	0	
12	10	6	1	0.5	1	Y	0	1	0	
13	10 + 5	6	0.5	0.25	0.75	Y	0	0	0	
14	10	6	0.25	1.5	0.5	Y	0	0	0	
15	7	4.5	0	0.25	0.25	Y	0	1	0	

Varroa Population Dynamics – Stellenbosch Date: 03/08/01

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Notes
1	9	4.5	0	0.5	2.5	Y	0	0	0	
2	5	1	0	0.063	0.5	Y	0	0	0	Likely swarm!
3	10	4	0.25	1	2	Y	0	1	0	
4	9	3	0	1	1	Y	0	3	0	
5	10	0.125	0	0.25	1.5	Young	0	2	0	Likely swarm!
6	8	3	0	0.5	0.75	Y	0	5	0	
7	10	4	0.75	0.5	1	Y	1 closed	1	0	
8	10	5	0.25	2.5	1.5	Y	0	0	0	
9	10	4.5	0.25	1.5	3	Y	0	0	0	
10	10	3	1	2	1.5	Y	0	0	0	
11	10	5	0.125	0.5	2	Y	0	0	0	
12	10	3	0	1.5	2.5	Y	0	4	0	
13	10	5	0.25	1	2	Y	0	0	0	
14	10	4.5	0	2.5	1	Y	0	0	0	
15	8	3.5	0	0.5	2	Y	0	1	0	

Varroa Population Dynamics – Stellenbosch Date: 31/08/01

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Notes
1	9	1.5	0	0.06	0.25	Y	0	1	0	Bees starving
2	5	0	0	0	0	Y	0	0	0	Bees starving
3	10	1.5	0	0	0	Y	0	0	0	Bees starving
4	8	1	0	0	0	Y	0	0	0	Bees starving
5	8	2	0	0.13	0.06	Y	0	3	0	Bees starving
6	4	0.5	0	0	0	Y	0	5	0	Bees starving
7	5	0	0	0	0	Y	0	0	0	Swarmed & Starving
8	8	0.5	0	0.06	0	Y	0	1	0	Swarmed (?) & Starving
9	6	1.5	0	0.5	0.13	Y	0	0	0	Bees starving
10	9	1.5	0	0	0	Y	0	0	0	Bees starving
11	10	3	0.13	0.25	0	Y	0	0	0	Bees starving
12	8	1	0	0	0	Y	0	5	0	Bees starving
13	7	0.25	0	0	0	Y	0	2	0	Swarmed (?) & Starving
14	10	3.5	0	0	0	Y	0	0	0	Bees starving
15	7	2	0	0	0.25	Y	0	0	0	Bees starving

Varroa Population Dynamics – Stellenbosch Date: 28/09/01

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Notes
1	10	5.5	.25	.25	2	Y	0	0	0	
2	3	0.25	0	0.125	0.125	N	8	0	0	
3	10	6	0.25	0.5	2	Y	0	2	0	
4	10	4.5	0.25	0.5	0.25	Y	0	4	0	
5	8	4.25	0.125	0.5	3	Y	0	3	0	
6										EMPTY
7										EMPTY
8	10	5	0.25	2	2	Y	0	3	0	
9	5	2.5	0	2	0.5	Y	0	1	0	
10	10	6.5	1.5	2	2	Y	0	0	0	
11	10++	6	0.5	0.5	1	Y	0	1	0	Super full of bees
12	7	3.5	0	0.5	2	Y	0	4	0	
13	8	3	0.06	0.25	2	Y	0	2	0	
14	10++	5	0.13	1.5	2	Y	0	1	0	Super full of bees
15	10++	6.5	1	0.25	1	Y	0	3	0	Super full of bees

Varroa Population Dynamics – Stellenbosch Date: 26/10/01

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Notes
1	10	5.5	.25	2.25	1	Y	0	0	0	
2										Bees Gone
3	10	6	0.125	2	0.5	Y	0	3	0	
4	10	5	0.25	1	0.5	Y	0	4	0	
5	10	4.5	0.25	1	2	Y	0	0	0	
6										EMPTY
7										EMPTY
8	10	4	0.25	3	1	Y	0	1	0	
9	8	3	0.125	2	2	Y	0	0	0	
10	10	6	1	2	0.5	Y	0	0	0	
11	10	4.5	0.25	2	1	Y	0	0	0	
12	7	3	0	0.25	3	Y	0	4	0	
13	8	Worker Brood	0	1.5	4	Young Q	0	0	0	
14	10	5	0.5	0.5	1	Y	0	0	0	
15	10	2.5	0	2	4	Young Q	0	1	0	

Varroa Population Dynamics – Stellenbosch Date: 09/11/01

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	10	4	0	1	2	Y	0	0	0	0	312	0.00
2												
3	10	5.5	0.063	2.25	0.5	Y	0	0	0	0	279	0.00
4	10	3.5	0.125	1	0.5	Y	0	3	0	0	352	0.00
5	10	4.5	0.063	1.5	2	Y	0	0	0	0	278	0.00
6												
7												
8	10	5	0.25	2	0.5	Y	0	0	0	0	308	0.00
9	8	3	0	2	3	Y	0	1	0	1	254	0.39
10	10	5	1	1	1	Y	1 open	0	0	1	317	0.32
11	10	5.5	0.63	2	0.125	Y	0	0	0	1	296	0.34
12	8	4	0	1	1	Y	0	2	0	0	392	0.00
13	6	1.5	0	1.5	3	Y	4 open	0	0	0	326	0.00
14	10	6	0.125	2	1	Y	0	1	0	0	262	0.00
15	7	3	0	0.125	2.5	Y	0	1	0	1	367	0.27

Varroa Population Dynamics – Stellenbosch Date: 14/01/02

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Notes
1	6	3	0	0.25	4	Y	0	1	0	
2										EMPTY
3	15	5.5	0.25	0.5	0.5	Y	0	1	0	
4	14	4.5	0	0.5	2	Y	0	2	0	
5	16	4	0.06	0.25	3	Y	0	0	0	
6										EMPTY
7										EMPTY
8	15	4.5	0.13	3	0.5	Y	0	1	0	
9	5	2.5	0.25	1.00	5	Y	0	0	0	
10	15	6	0.25	0.25	0.5	Y	2	1	0	
11	14	5	0	4	2	Y	0	0	0	
12	8	3.5	0	0.5	3	Y	0	2	0	
13	5	2.50 Worker Brood	0	0.13	2	N	0	0	0	
14	18	5	0.25	3	0	Y	0	0	0	
15	14	5	0.13	0.5	3	Y	0	0	0	

Varroa Population Dynamics – Stellenbosch Date: 29/01/02

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Notes
1	8	2	0	1	4	Y	0	0	0	
2										EMPTY
3	15	5.5	0.125	1	2	Y	0	1	0	
4	10	4	0	2	1	Y	0	3	0	
5	12	3.5	0	1.5	4	Y	0	0	0	
6										EMPTY
7										EMPTY
8	10	3.5	0.125	3	0.5	Y	0	1	0	
9	6	3	0	1.5	5	Y	0	0	0	
10	12	6	0.25	2	1	Y	0	0	0	
11	10	3.5	0	2	2	Y	0	0	0	
12	8	4	0	0.5	2	Y	0	4	0	
13	5	2	0	0.25	2	Y	0	0	0	
14	14	5	0	3	0.5	Y	0	0	0	
15	10	5.5	0	0.5	3	Y	0	1	0	

Varroa Population Dynamics – Stellenbosch Date: 25/02/02

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Notes
1	4	0	0	0.5	4	N	2	0	0	SWARMED
2										EMPTY
3	10	5	0.125	0.75	3	Y	0	1	0	
4	10	4	0	3.5	1	Y	0	0	0	
5	10	3.5	0	1.5	4	Y	0	0	0	
6										EMPTY
7										EMPTY
8	4	0	0	5	3	N	1	0	0	SWARMED
9	5	2	0,063	2	2	Y	0	0	0	
10	10	4.5	0.25	2	1	Y	0	1	0	
11	10	5	0.125	2.5	1.5	Y	0	0	0	
12	10	4	0.063	1.5	1	Y	0	2	0	
13	6	3	0	1	2	Y	0	0	0	
14	12	5	0	5	0	Y	0	0	0	
15	10	5	0	1	2	Y	0	0	0	

Varroa Population Dynamics – Stellenbosch Date: 26/03/02

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Notes
1										EMPTY
2										EMPTY
3	15	2.5	0	1	0.5	Y	0	0	0	
4	12	2.5	0	1.5	0.25	Y	0	0	0	
5	8	2	0	1	6	Y	0	0	0	
6										EMPTY
7										EMPTY
8	7	0.5	0	4	2	Young Q	3, 1E	0	0	
9	6	LW brood	0	2	5	?	0	0	0	
10	13	3	0	1	1	Y	0	0	0	
11	13	4	0	2	1	Y	0	0	0	
12	10	4	0	2	2	Y	0	0	0	
13	5	3	0	0.25	2	Y	0	0	0	
14	15	3	0	6	1	Y	0	0	0	
15	14	4	0	2.5	3	Y	0	0	0	

Varroa Population Dynamics – Stellenbosch Date: 22/04/02

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Notes
1										EMPTY
2										EMPTY
3	13	4	0	0.25	1.5	Y	0	0	0	
4	10	2	0	0.5	2	Y	0	0	0	
5	10	3	0.13	0.75	5	Y	2	0	0	
6										EMPTY
7										EMPTY
8	3	LW brood	0	1	0.25	N	2	0	0	
9	7	1.5	0	1	6	Y	0	0	0	
10	12	3.5	0	2	2	Y	0	0	0	
11	15	4	0	2	2.5	Y	0	0	0	
12	10	4	0	1.5	4	Y	0	0	0	
13	9	4	0	1	1	Y	0	0	0	
14	15	3.5	0.25	1	4	Y	0	0	0	
15	15	4.5	0	1	4	Y	0	0	0	

Varroa Population Dynamics – Stellenbosch Date: 27/05/02

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Notes
1										EMPTY
2										EMPTY
3	10	2	0	0.13	0	Y	0	0	0	
4	10	1	0	0.13	0.5	Y	0	0	0	
5	10	2	0	0.5	4	Y	0	0	0	
6										EMPTY
7										EMPTY
8	3	LW brood	0	1	0	N	0	0	0	
9	8	2	0	2	6	Y	0	0	0	
10	10	0	0	0.5	0.5	?	0	0	0	
11	13	4	0	2	2	Y	0	0	0	
12	10	2	0	2	3	Y	0	0	0	
13	7	1.5	0	0.13	1	Y	0	0	0	
14	12	2	0	3.5	0.5	Y	0	0	0	
15	15	2.5	0	1	5	Y	0	0	0	

Varroa Population Dynamics – Kwazulu / Natal Date: 14 /06 /2001

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load Screen count
1	25	5	3/4	2	13	yes	no	1	0	0	420	0
2	24	5 .5	1/4	2.5	14	yes	no	1	0	0	400	0
3												
4	18	6	0	1.5	8	yes	no	1	0	0	380	0
5												
6												
7	14	4	1/2	2.5	9	yes	no	1	0	0	390	0
8	13	5	0	2	9	yes	no	1	0	0	400	0
9	22	6	1/4	2	14	yes	no	1	0	0	380	0
10	17	5	3/4	2.5	13	yes	no	1	0	0	400	0

Notes: 1 / Colony no 3 queenless with multiple eggs.
2 / Colonies no 5 & 6 vandalised beyond recovery.
3 / Moved group A from Eldoret site to Wondergeluk site.
4 / Removed strips and re – hived.

Varroa Population Dynamics – Kwazulu /Natal Date: 28/06/2001

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	26	6	0	3	22	yes	no	1	0	0	450	0
2	25	5.5	0	2.5	22	yes	no	1	0	0	400	0
3												
4	20	6	0	1.5	12	yes	no	1	0	0	400	0
5												
6												
7	16	5	1/3	3	13	yes	no	1	0	0	420	0
8	14	6	1/4	1.5	14	yes	no	1	0	0	380	0
9	25	7	0	2.5	22	yes	no	1	0	0	380	0
10	20	5	1/3	2	12	yes	no	1	0	0	440	0

Notes: 1 / Insert 20 Varroa into the above (r.e. dates)1 : 29/06; 2 : 28/06; 4 : 29/06; 7 : 28 /06; 8 : 29/06; 9 : 30/06; 10 : 30/06
2 / Abort on colony 3 (*capensis* infestation)

Varroa Population Dynamics – Kwazulu /Natal Date: 12 /07/2001

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	25	6	0	2.75	18	yes	no	1	0			
2	25	5.5	0	2.5	19	yes	no	1	0			
3												
4	20	6	0	1.5	8	yes	no	1	0			
5												
6												
7	16	5	.0	3	8	yes	no	1	0			
8	14	6	0	2	9	yes	no	1	0			
9	22	7	0	3	19	yes	no	1	0			
10	20	6	0	2	9	yes	no	1	0			

Varroa Population Dynamics – Kwazulu / Natal Date:08/08/2001

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	14	4.5	0	2.5	14	Yes	0	1	0			
2	13	4	0	2.5	11	Yes	0	1	0			
3												
4	12	4.5	0	2.5	9	Yes	0	1	0			
5												
6												
7	13	4	0	2	14	Yes	0	1	0			
8	12	4	0	.5	6	Yes	0	1	0			
9	16	6	0	4	15	Yes	0	1	0			
10	13	5	0	2	9	Yes	0	1	0			

Varroa Population Dynamics – Kwazulu / Natal Date :06/09/2001

Colony number	Frames of bees	Frames of Worker Brood	Frames of Drone brood	Frames of Stored pollen	Frames of Stored honey	Queen present	Queen Cells	Chalk brood (0 -5)	E F B (0 – 5)	Number of Varroa in Varroa Sample	Number of bees in varroa sample	Varroa load
1	11	3	0	2	16	yes	0	0	0			
2	12	4	0	2	7	yes	0	0	0			
4	11	4	0	2	9	yes	0	1	0			
7	12	4	0	2	14	yes	0	1	0			
8	11	4	0	0.5	5	yes	0	1	0			
9	15	5	0	3	14	yes	0	1	0			
10	13	5	0	1.5	9	yes	0	1	0			

Varroa Population Dynamics – Kwazulu / Natal Date : 04 /10 /2001

Colony number	Frames of bees	Frames of Worker brood	Frames of Drone brood	Frames of Stored pollen	Frames of Stored honey	Queen present	Queen cells	Chalk Brood (0 – 5)	E.F.B (0 – 5)	Number of Varroa in varroa sample	Number of bees in varroa sample	Varroa load
1	17	8	0.5	1.25	13	yes	3	1	0			
2	12	6	0.5	1.5	1	yes		1	0			
4	13	10	2	2.5	9	yes	3	1	0			
7	12	7	0.75	1	6	yes	0	0	0			
8	13	9	2	2	8	yes		1	0			
9	20	8	1.5	2.5	18	yes	1	1	0			
10	14	7	1.5	1.5	7	yes	0	0	0			

Varroa Population Dynamics – Kwazulu / Natal Date:01/11/2001

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	18	6	0.5	2	16	yes	0	1	0			
2	13	5	0.5	1.5	5	yes	0	1	0			
4	14	8	0.5	2	9	yes	0	1	0			
7	14	7	0.5	1	7	yes	0	0	0			
8	14	6	1	1.5	8	yes	0	1	0			
9	18	6	0	1.5	18	yes	1	1	0			
10	16	6	0.5	1	8	yes	0	0	0			

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Varroa Population Dynamics – Kwazulu / Natal Date:29/11/2001

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	20	5	0.5	1.5	18	yes	0	1	0			
2	14	4	0	0.5	12	Yes	0	1	0			
4	16	6	0	1.5	11	Yes	0	1	0			
7	16	5	0	1	10	Yes	0	0	0			
8	13	4	0	1.5	8	Yes	0	1	0			
9	20	4	0	2	18	Yes	4	1	0			
10	11	3	0	1	11	Yes	3	0	0			

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Varroa Population Dynamics – Kwazulu / Natal Date: 28/12/2001

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	16	4	0.5	1	16	yes	1	1	0			
2	13	4	0	0.5	12	Yes	0	1	0			
4	16	6	0	1	10	Yes	0	1	0			
7	13	5	0	1.5	9	Yes	0	0	0			
8	13	4	0	1.5	9	Yes	0	0	0			
9	16	4	0	1.5	16	Yes	0	1	0			
10	11	4	0	1	9	Yes	0	0	0			

Varroa Population Dynamics – Kwazulu / Natal Date: 25/01/2002

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	10	4	1.5	2	7	Yes	0	1	0			
2	7	7	0.5	1	7	Yes	1	1	0			
3												
4	12	5	1.5	1	11	Yes	0	1	0			
5												
6												
7	12.5	3	1	1	5	Yes	0	0	0			
8	11	4	0	1	7	Yes	0	0	0			
9	12	5	0	2	9	Yes	2	0	0			
10	15	3	0	2	5	yes	0	0	0			

Varroa Population Dynamics – Kwazulu / Natal Date :21/02/2001

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	10	3	0.5	1	5	yes	0	1	0			
2	9	5	0	0.25	6	yes	0	0	0			
3												
4	11	3	0.25	1	6	yes	0	0	0			
5												
6												
7	11	4	0	1	6	yes	0	0	0			
8												
9	11	4	0	0.5	4	yes	0	0	0			
10	12	4	0.33	0.25	3	yes	0	0	0			

Varroa Population Dynamics – Kwazulu / Natal Date: 21/03/2002

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	10	1.5	0	0.5	3	yes	0	0	0			
2	10	2.25	0	1.25	3	yes	0	0	0			
3												
4	10	3	0	1.25	10	yes	0	0	0			
5												
6												
7	11	3.5	.25	3.25	6	yes	0	0	0			
8												
9	12	3	0	1.20	4	yes	0	0	0			
10	11	2.5	0	1	4	yes	0	0	0			

Varroa Population Dynamics – Kwazulu / Natal Date:18/04/2002

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	12	6	1	4	18	yes	0	0	0			
2	13	7	1	3.5	16	yes	0	0	0			
3												
4	12	6	1	2.5	17	Yes	0	0	0			
5												
6												
7	13	6	3.25	3	13	yes	0	0	0			
8												
9	13	7	1	3	16	yes	0	0	0			
10	14	5	1	4	16	yes	0	0	0			

Varroa Population Dynamics – Kwazulu / Natal Date:13/06/2002

Colony Number	Frames of Bees	Frames of Worker Brood	Frames of Drone Brood	Frames of Stored Pollen	Frames of Stored Honey	Queen Present	Queen Cells	Chalk-brood (0-5)	EFB (0-5)	Number of varroa in varroa sample	Number of bees in varroa sample	Varroa Load
1	25	4.5	0.5	6	36	yes	0	1	0			
2	25	4	0	3.5	4	yes	0	0	0			
3												
4	12	1	0	2	3	yes	0	0.75	0			
5												
6												
7	17	3	0	4	6	yes	0	0	0			
8												
9	25	4.5	0	4	4	yes	0	0	0			
10	15	2.5	0.25	3	6	yes	0	0	0			