An assessment of different beekeeping practices in South Africa based on their needs (bee forage use), services (pollination services) and threats (hive theft and vandalism)

by

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Declaration

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General summary

Two honey bee subspecies indigenous to South Africa, *Apis mellifera capensis* Escholtz (Cape honey bee) and *Apis mellifera scutellata* Lepeletier, are actively managed by beekeepers for honey production, other bee related products (e.g. bees wax) and to provide pollination services. Historic records show that managed colonies of both subspecies to rely on a mix of exotic - (Eucalyptus species, agricultural crops, weeds and suburban plantings) and indigenous forage (genera and vegetation units). However, their extent of use and importance for honey production, pollination, colony maintenance and swarm trapping (together referred to as beekeeping practices), have not been fully explored across South Africa. Additionally, acts of hive theft and vandalism have become a key concern for the industry, threatening and potentially limiting beekeeping in some areas. Related to this is also a concern that growers need more colonies for crop pollination than beekeepers can supply. Furthermore, beekeepers currently face challenges related with their industries' organisation and governance.

The broad aim of my study was to understand the multiple challenges facing the South African beekeeping industry and to contribute detailed knowledge on forage use for beekeeping practices in South Africa. The knowledge thereof would provide a practical understanding of these aspects and ultimately contribute towards the planning and decision making where beekeeping is concerned. Using two questionnaire surveys I determined: 1) the current status of beekeeping in South Africa based on beekeeper opinion; 2) forage use for honey production; 3) the use and demand for pollination services; 4) forage use for colony maintenance and swarm trapping; and 5) trends and implications of hive theft and vandalism for the beekeeping industry. The forage use survey captured the most managed colonies (50067) and respondents (218) compared to the hive theft and vandalism survey, which had 161 respondents constituting 48386 managed colonies.

Results showed that beekeepers have concerns similar to those captured in previous studies and reports, with the lack and loss of forage being very important. Across all four beekeeping practices exotic forage was predominantly used, although the level of preference differed provincially. The important forage types and significant species were highlighted in each province on the basis of number of colonies using individual forage species and followed a similar trend to that of forage categories. Some species were both important and of significant

use for more than one beekeeping practice (e.g. *Eucalyptus grandis*, *Eucalyptus cladocalyx*, *Helianthus annuus*, Macadamia spp. and *Senegalia mellifera*) in the same or different provinces. The preference of trapping swarms on different forage highlighted the value of this practice compared to hive splitting, removal of problem swarms and buying of colonies from other beekeepers. Also, the number of localities used for forage differed across provinces, although in some cases the same locality was used for more than one beekeeping practice. Furthermore, some beekeepers used localities situated in their neighbouring provinces. These results suggest that exotics remain the predominantly used forage source for beekeeping in South Africa, and that some forage types and sources are more important that others in their respective localities. Also, provinces have different forage needs in relation to the different beekeeping practices. Therefore, the planning, management and promotion of bee forage at regional or national level should consider all four practices.

It was challenging to obtain reliable planting data (given in hectares) and number of colonies used for pollination per hectare for respective crops. This prohibited a thorough understanding of the relationship between pollination service provision and demand, highlighting the importance of formally capturing this data. However, the derived results indicated pollination demands to be stable at a national level while inconclusive for certain provinces (e.g. Free State). The Western Cape had the highest pollination demand overall, while crops such as oil seeds, deciduous-, subtropical fruit, and nuts had high pollination demands.

Trends in hive theft and vandalism showed most losses to occur through human induced vandalism. Although the magnitude of losses varied between provinces, factors contributing to the losses were similar with respect to the positioning (agricultural lands) and visibility (medium) of the colonies within the landscape. This means that for these colonies to continue accessing forage for various beekeeping practices, various sites need to be protected from theft and vandalism.

Algemene opsomming

Twee Suid-Afrikaanse heuningby subspesies, *Apis mellifera capensis* Escholtz (Kaapse heuningby) en *Apis mellifera scutellata* Lepeletier, word deur byeboere aktief bestuur om heuning, ander byprodukte (bv. byewas) en bestuiwingsdienste te verskaf. Historiese rekords dui daarop dat bestuurde kolonies van beide subspesies afhanklik is van ŉ mengsel van eksotiese (Eucalyptus spesies, landbougewasse, onkruide en voorstedelike aanplantings) en inheemse byvoer (spesies en plantegroei tipes). Nietemin is hul omvang van gebruik en belangrikheid vir heuning produksie, bestuiwing, onderhoud van kolonies en swerm-vang (staan saam bekend as byeboerpraktyke) nog nie omvattend in Suid-Afrika ondersoek nie. Bykomend, word die pleeg van korfdiefstal en vandalisme ŉ bekommernis vir die industrie, wat byeboerdery in sommige areas bedreig en moontlik beperk. Samehorend hiermee is daar ook ŉ bekommernis dat gewasboere meer korwe vir bestuwing kort as wat byeboere kan bied. Verder staar byeboere ook uitdagings in die gesig wat betref die organisering en regulering van hul industrie.

Die breë doel van my studie was om die veelvoudige uitdagings wat Suid-Afrikaanse byeboere ervaar te verstaan, en gedetailleerde kennis oor die gebruik van voer in Suid-Afrikaanse byeboerpraktyke te verskaf. Kennis hiervan sou ŉ praktiese begrip van hierdie aspekte verskaf, en uiteindelik bydrae tot die beplanning en besluitneming in byeboerdery. Deur twee vraelys-opnames te gebruik het ek die volgende bepaal: 1) die huidige toestand van byeboerdery in Suid-Afrika volgens byeboere se menings; 2) die gebruik van byvoer vir heuning produksie; 3) die aanvraag en gebruik van bestuiwingsdienste; 4) gebruik van byvoer vir die onderhoud van kolonies en swerm-vang; en 5) die tendense en gevolge van korfdiefstal en vandalisme vir die byeboerindustrie. Die byvoer-gebruik opname het die meeste korwe (50067) en respondente (218) gelewer, teen die korfdiefstal-en-vandalisme opname wat slegs 161 responsdente, wat 48386 korwe verteenwoordig, gehad het.

Bevindings het gewys dat byeboere se bekommernisse eenders was as wat vorige opnames en studies gelewer het, met die beperking en verlies van byvoer wat baie belangrik geag is. Regoor al vier byeboerpraktyke was die gebruik van eksotiese byvoer oorweeggend, al het die graad hiervan provinsiaal verskil het. Die belangrike byvoer tipes en betekenisvolle spesies van elke provinsie is vasgestel in terme van die aantal kolonies wat ŉ byvoer-spesies

gebruik, wat ŉ soortgelyke tendens as die byvoer kategorieë gevolg het. Sommige spesies was beide belangrik en beduidend vir die gebruik van meer as een byeboerpraktyk (bv. *Eucalyptus grandis*, *Eucalyptus cladocalyx*, *Helianthus annuus*, Macadamia spp. en *Senegalia mellifera*) in dieselfde of verskillende provinsies. Swerm-vang wat verkies is bo korfverdeling, verwydering van probleem korwe en koop van korwe by ander byeboere, dui die waarde van hierdie praktyk aan. Die aantal plekke wat vir byvoer benut was, was ook verskillend vir provinsies, al was dieselfde plek vir meer as een byeboerpraktyk gebruik. Verder het sommige byeboere plekke gebruik in aangrensende provinsies. Hierdie bevindings stel voor dat eksotiese byvoer bly steeds die mees gebruikte bron vir byeboerdery in Suid-Afrika, en dat in sekere plekke sommige byvoer tipes en bronne meer belangrik is as ander. Provinsies het ook verskillende byvoer behoeftes vir spesifieke byeboerderypraktyke. Dus moet die beplanning, bestuur en bevordering van heuningbyvoer op ŉ streeks en nasionale vlak in ag geneem word vir al vier boerderypraktyke.

Dit was uitdagend om betroubare aanplantings data (gegewe in hektaar) en die aantal korwe wat per hektaar gebruik word in te win. Dit het verhoed dat ŉ deeglike begrip van die verhouding tussen die lewering van bestuiwingsdienste en die aanvraag daarvan, verkry is, en dui aan hoe belangrik dit is om hierdie data formeel in te samel. Nietemin het die afgeleide bevindinge gewys dat die aanvraag vir bestuiwing stabiel is op ŉ nasionale vlak, terwyl dit onseker is vir sekere provinsies (bv. die Vrystaat). Die Wes-Kaap Provinsie het die hoogste algehele bestuiwingsaanvraag gehad, terwyl gewasse soos saadolies, sagte- en sub-tropiese vrugte, en neute ŉ hoë bestuiwingsaanvraag het.

Tendense in korfdiefstal en vandalisme het gewys dat meeste verliese deur mens-veroorsaakde vandalisme plaasvind. Al het die groottes van verliese gevarieer tussen provinsies, was die faktore wat tot die verliese bygedra het eenders was met betrekking tot die plasing (landbou areas) en sigbaarheid (medium) van korwe in die landskap. Dit beteken dat vir die kolonies wat aaneenlopende toegang tot byvoer moet kry vir verskeie byeboerpraktyke, moet verkeie stande van korfdiefstal en vandalisme beskerm word.

Dedication

I dedicate this thesis to:

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Chapter 1
General introduction

1.1 The practice of beekeeping

Beekeeping involves the maintenance of honey bee colonies in hives for the purpose of harvesting bee related products (i.e. honey, bees wax, and propolis) and the rendering of pollination services to growers of insect pollinator dependent crops (Crane 1983 & 1992). The earliest records of man's association with bees date back to 15000 BC and this is evident in Spanish cave paintings (Clarke 2012). Crane (1992) indicates that the Mediterranean and Middle East areas were key areas of early beekeeping development. Egypt also houses some vital historic documentation of beekeeping dating back to 1450 BC with detailed drawings located within some of the Egyptian royal tombs (Crane 1983).

The earliest years of beekeeping was characterised by regular harvesting of honey from naturally occurring hives, which were protected by the beekeeper. This remains the mode of beekeeping in many parts of the world. Then came log hive beekeeping, and only after that beekeeping in bark hives, clay pots and baskets (Smith 1960; Crane 1992). For those bees located and left to nest in rocks and tree hollows, ownership was acquired by some form of marking (i.e. placing a few twigs or axe marking) to denote ownership (Crane 1983). This also relates to early beekeeping years in South Africa. Bee nests were located by following honey-guide birds and, upon their discovery; nests would be marked to claim ownership (Guy 1972). The Khoikhoi, also known as Hottentots, were great pastoralists and honey gatherers in the drier western parts of the country (Guy 1972).

The first movable frame hive can be dated to about 1806, designed by a Ukrainian beekeeper (Petr Prokopovich). In 1851, Lorenzo Lorraine Langstroth developed the "next generation" movable-frame wooden hive which is the foundation of managed beekeeping as we know it (Johannsmeier 2001). Although beekeeping tools and aids have undergone tremendous changes since the 1800's, most modern hives used today throughout the world are still based on 1851 design of Langstroth. Moveable-frame hives transformed the use of honey bee related product and services. Bee colonies were now easily moved around to new environments to take advantage of good honey yields and to meet pollination demands (vanEngelsdorp & Meixner 2010). Man has since mastered the art of domesticating and utilising honey bees for their own benefit. Although there are about 20 000 known bee species globally, with 3 000 species confined to the African continent, only *Apis mellifera* (honey bees) has to date been transported by man to most parts of the world where it never existed (Johannsmeier 2001). Only one of the nine known honey bee species occurs in Africa, that being the Western Honey bee, *Apis mellifera* (Johannsmeier 2001). Within South Africa, two indigenous subspecies of *Apis mellifera capensis* (Cape honey bee) and *Apis mellifera scutellata* (African/Savannah honey bee) can be found (Hepburn & Radloff 1998). The two subspecies differ by their geographical distribution and several other morphological and behavioural traits (see Johannsmeier 2001; du Preez 2010).

A common dominator in any form of beekeeping, irrespective of the species managed, is the availability and accessibility to forage. Honey bee health depends on forage availability amongst other things. Of great importance is the quantity and quality of the forage (Chauzat *et al*. 2009). Simply put, if forage is not available or accessible, and also at the desired quality, then beekeeping would cease to exist, taking away all the derived benefits that are associated. This is from honey production to the pollination services for agricultural crops. However, the degree of the dependence of beekeeping on the availability of forage resources is not well understood. I will specifically address this aspect through investigating different beekeeping practices and their forage requirements in the context of the South African beekeeping industry.

1.1.1 Importance of managed honey bees for commercial crop pollination

Intensified farming practices due to increased demands and the need to achieve high yields, have left little to no natural areas around farms, thereby depriving crops of the available pollination ecosystem services provided by most wild insect pollinators (Biesmeijer *et al*. 2006). Not only has the production of several crops increased over time, the simultaneous mass flowering of numerous hundreds of hectares of farmland poses a challenge to any farming system which lays outside an adequate natural assemblage of pollinators or in an area of exclusively intense agriculture. Consequently, the use of managed honey bees for pollination is inevitable since these are the only easily available insect pollinator that can be supplied in great numbers to a wide variety of crops (Aizen *et al*. 2009).

Although the contribution of honey bees (wild and managed) to agricultural crop pollination is widely acknowledged (Klein *et al*. 2007; Kremen *et al*. 2007), the ideal method of economic valuation of insect pollination remains debated (e.g. Morse & Calderone 2000; Allsopp *et al*. 2008; Gallai *et al* 2009). However, this does not reduce the importance of pollination services performed by honey bees in the agricultural sector (Aizen *et al*. 2009). Furthermore, the proportion of pollinator-dependent crops cultivated globally is set to increase, suggesting that the demand for pollination is also set to increase (Aizen *et al*. 2009). The bulk of the pollination service is expected to be performed by managed honey bees. The supply and demand of managed honey bees for crop pollination has been investigated elsewhere in the world (Breeze *et al*. 2014), but not yet in South Africa. Therefore, I will in this study investigate the current and future planting regimes of various pollinator dependent crops in South Africa together with their associated demand for managed pollination services.

1.1.2 Sustainable beekeeper livelihoods

The dawn of beekeeping practices saw beekeepers mostly benefiting from harvesting and selling honey (Chauzat *et al*. 2009). However, honey is just one of the several products that can be harvested. Other bee related products such as beeswax, pollen and propolis, royal jelly and venom are also available on the market (FAO 2009). Bees and beekeeping contribute to peoples' livelihoods in many aspects. Currently, pollination services rendered for agricultural crop pollination is the biggest source of income for beekeepers (Morse & Calderone 2000; Sagili & Burgett 2011). The removal of problem swarms in spring to summer periods is another way for beekeepers to source an income as they charge a call out and bee removal fee (Clark 2012). However, the payment structure for these swarm removals varies greatly. The aspect of job creation is also of importance in the beekeeping industry, both in agriculture that depends on honey bee pollination and beekeeping itself. At times, those beekeepers running bigger operations have the capacity to employ fewer people from surrounding communities where hives are kept (Johannsmeier 2001; Allsopp & Cherry 2004).

1.1.3 Honey bee diseases, pests, and pathogens

Honey bee diseases, parasites, and pests have been widely documented in relation to their negative impact on colony productivity and survival (Finley *et al*. 1996; De Jong 1997; Morse & Flottum 1997; Anderson & Trueman 2000; Genersch 2010; Rosenkranz *et al*. 2010). Amongst others, Allsopp (2006) labelled *Varroa destructor* (commonly known as the varroa mite) as the most serious pest of honey bees in the 20th century as it was responsible for multitudes of honey bee colony death across Europe and the USA. It was established that *V. desructor* was responsible for about 60% of commercial honey bee colony losses and accounted for a further 95% of wild populations (Finley *et al*. 1996; Page 1998). To date, there is no total effective treatment for varroa mite but several chemicals have been demonstrated to be effective control options (see Fries 1997; Anderson & Allsopp 1999). There are also several viruses associated with *V. destructor* infestations and these are unevenly spread globally (Ellis & Munn 2005). Some of these include Deformed Wing Virus (DWV), Acute Bee Paralysis Virus (ABPV) (vanEngelsdorp & Meixner 2010), while others such as Kashmir Bee Virus (KBV) and Israeli Acute Paralysis Virus (IAPV) are thought to at times be present even with the absence of varroa mite (Shen *et al*. 2005; Cox-Foster & vanEngelsdorp 2009).

Nosema apis and *Nosema cerena* are also two other well know bee pathogens (Fries *et al*. 1996), which cause inflammation and damage in honey bee guts, their epithelial cells in particular. They reduce lifespan of individual bees, reduce colony performance and increase winter mortality (Higes *et al*. 2008).Then there is American foulbrood (AFB), the most widespread and destructive bee brood disease and is caused by the spore forming *Paenibacillus larvae* (Genersch *et al*. 2006). AFB was the most economically import diseases of honey bees worldwide prior to the arrival of varroa mite and is still one of the most deadly bee diseases (Genersch 2010). The extent of honey bee colony losses due to AFB at a global scale is not fully documented; however, Eischen *et al*. (2005) estimated that there was approximately $5 million in economic loss linked to AFB in the USA in the early 2000s.

To date, the hive burning practise is very common and effective in the fight against AFB since antibiotics treatment is limited to some countries (vanEngelsdorp & Meixner 2010). In South Africa, AFB resurfaced again in 2014 after the initial outbreak in 2009. Unconfirmed reports suggest the Western Cape Province to be the hardest hit, with beekeepers losing close to 40% of their colonies. The source of the outbreak is yet to be established, so is the extent of the spread. Some beekeepers are currently resorting to hot wax dipping at 180 °C, rather than hive burning, which is reported to kill the spores successfully (Samuels pers. comm. 2013).

1.1.4 Colony Collapse Disorder (CCD)

Colony Collapse Disorder made headlines globally with unexplained colony loses in the United States and some European countries since 2006 (Neumann & Carreck 2010). As vanEngelsdorp *et al*. (2009) explains, CCD is characterized by the disappearance of adult honey bees from the hive. At times, the queen is left behind (alive) with substantial amount of brood. No dead bees are found in or around the hive and food stores are left untouched by robbing bees or other pests. According to Johnson (2010), there is no clear single factor linked to CCD and there might even be different factors working in a combination or synergistically. Some of the factors linked to CCD are pesticide use, parasites, pathogens and viruses, poor nutrition and even stress of being overworked during crop pollination. Colony loses in the light of CCD are widely documented (see Biesmeijer *et al*. 2006; Cox-Foster *et al*. 2007; vanEngelsdorp *et al*. 2008; Potts *et al*. 2010) while funding and research has increased drastically in trying to get answers surrounding CCD and its implications on honey bee colonies. The question still remains whether CCD really does exist, or whether various combinations of bee threats are simply misnamed CCD – which most people now conclude just to be the multitude of factors acting together.

1.1.5 The need to conserve honey bees

Many nations have recently been concerned about the recent declines in honey bees and other insect pollinators (Potts *et al*. 2010). In particular, declines in honey bees pose a dilemma given that they are not indigenous in most parts of the world where they occur (i.e. United States of America). Therefore, conservation may not seem applicable to them. In contrast, for honey bees in native ranges (i.e. African countries), conservation may only be applicable to wild, but not managed population. However, drivers relating to declines are not restricted to the honey bee population origin or conservation status. This relates to mostly to habitat loss, forage shortage and the misuse of various agrochemicals.

For the African continent in particular that is dependent on harvesting wild populations for beekeeping practices, it is crucial that the populations are protected (Dietemann *et al*. 2009). More so, native honey bees are important for the pollination of numerous plants within various ecosystems. They keep various ecological components intact (Kearns & Inouye 1997). In essence, honey bees are important pollinators for plant communities within various habitats and landscapes (Kevan 1999). The relationship between honey bees and various plants is co-dependent as the two evolved together over time (Proctor *et al*. 1996). Therefore both will have their life cycle and wellbeing compromised at the absence of this relationship.

In conjunction, the importance of honey bees to agricultural crop pollination cannot be ignored (Klein *et al*. 2007) as their absence in providing pollination services will impact negatively on food security (Aizen *et al*. 2008). This renders an urgent need to find sustainable ways of ensuring honey bee populations remain viable and health to render pollination services to pollinator dependent crops (Calderone 2012) where they are native or introduced.

1.2 Use of forage for beekeeping

Apis mellifera is either indigenous or exotic in different areas globally, but still forms part of an areas' ecosystem and therefore depends on such ecosystems for habitats and forage (Dietemann *et al*. 2009). In these areas, forage is available from both exotic and indigenous flora (Levy 2011). A diverse diet is essential for honey bees because pollen variety helps them synthesize various enzymes necessary to detoxify (i.e. pesticides and diseases) and operate their immune systems optimally (Alaux *et al*. 2010). This keeps them healthy and productive. Gilliam (1986) and vanEngelsdorp *et al*. (2008) also emphasize the need for good diverse nutrition as malnourishment and starvation is one of the leading causes of bee mortality as a result of a compromised immune system.

Generally, honey bee foraging patterns depends on the amount of food (pollen and nectar) required by the colony at a particular time (Pankiw *et al*. 1998). Also, foragers may have preferences of various nectar and pollen sources of plants when various plants bloom at the same time in the environment (Bilisik *et al*. 2008). Under natural conditions (unmanaged populations), honey bees would normally forage on whatever forage is available within the vicinity – flying from anything between five (5) to seven (7) kilometres (Johannsmeier 2001). During forage shortage periods, they would either rob nearest hives or abscond in search for better forage source areas (Winston 1991; Beekman & Ratnieks 2001). Also, hive activity and productivity may be reduced (e.g. number of eggs the queen lays) to counter forage shortages.

Under beekeeping circumstances, beekeepers have to provide additional forage in the absence of immediate available forage within the environment by either moving hives to new forage rich sites or by supplementary feeding (Somerville 2000). This often means long travelling hours in order to avoid robbing among colonies or absconding – as this has the potential to affect hive health and productivity. Beekeepers that understand and know the importance of different plants to different beekeeping practices (as well as honey bee requirements at various stages of their life cycle) have a great advantage (Aston & Bucknall 2004). The lack of good forage means little to no honey production and poor colonies for pollination services provision. In certain instances massive forage abundance and availability (spring to summer months) is necessary to trigger swarming in wild populations (see Gerald & Combs 1972; Schmidt & Thoenes 1987). This enables beekeepers to trap swarms in order to increase their current stocks or replace those lost (see Johannsmeier 2001; Mouton 2011). This aspect is often misunderstood and lacks adequate data. In this study I will provide detailed information on this practice in South Africa and outline various forage sources that make swarm trapping possible.

Over time changes in land-use and agricultural practices have contributed extensively to habitat loss and degradation (Goulson *et al*. 2005) which in turn leads to the loss of critical forage resources (Williams 2005). This has placed unnecessary pressure on beekeepers as they have to continuously search for good suitable apiary sites on which to productively keep bees. In most instances, beekeepers don't even own any of the land that can be used to keep bees (Kellison 2009), therefore requiring some form of agreement (at times with payment) to occupy a potential apiary site.

1.3 Threats to forage use by beekeepers

1.3.1 Change in land use

Habitat loss is one of the biggest factors impacting honey bee and other insect pollinator declines (Brown & Paxton 2009). This is supported by Naug (2009) who correlated colony losses with percentage developed land area and found a significant positive correlation. Thus the degradation or loss of desirable nesting and foraging areas contributes to bee population declines. Land management and agricultural practise also contribute to reduced forage as a result of expanding agricultural fields at the expense of natural vegetation as well as the planting of monoculture that removes the diversity and quality of available forage (Kearns & Inouye 1997; Alaux *et al*. 2010; Levy 2011). At the same time, honey bees are brought into monoculture fields to provide pollination, leaving them with highly compromised nutrition during the pollination period (vanEngelsdorp & Meixner 2010).

Invasive alien plants species have the capacity to provide good additional forage to honey bees, but are mostly problematic and globally threaten many ecosystems and their functions (Pimentel *et al*. 2005; Charkes & Dukes 2006). This has led to their removal in most sensitive areas (i.e. water catchments). For South Africa in particular, the Working for Water programme (WfW) is tasked with ensuring the removal and control of various alien invasive plants to save water resources (see Binns *et al*. 2001). Unfortunately, various Eucalyptus species that are important honey bee forage have been targeted (see Allsopp & Cherry 2004). Most of these species have subsequently been removed or are in the process of being removed. A practice that has been met with resistance from the beekeeping industry as Eucalyptus is regarded as one of the best forage source in South Africa (see Johannsmeier 2001; Hutton-Squire 2014). This discord has also lead to the bases of my research, as there was a need to establish important bee forage plants in context to relevant beekeeping practices.

1.3.2 Pesticide use in agricultural areas

The large scale production of much of commercial agriculture depends on pollination services provided by honey bees (Aizen *et al*. 2009), the single most import crop pollinator worldwide (McGregor 1976; Morse 1991; Klein *et al*. 2007). Farmers depend on honey bees for the pollination of their crops and must constantly maintain a delicate balance between protecting their crops from pests and pathogens, and protecting the insects that are necessary to pollinate these crops (Klein *et al*. 2007), as in most instances, honey bees are vulnerable to many of the insecticides used to control damaging pests (Aliouane *et al*. 2009). Common insecticides such as neonicotinoids and pyrethroids have been shown to affect learning, foraging activities, and nest site orientation for honey bees at sub-lethal doses (Desneux *et al*. 2007; Aliouane *et al*. 2009; Spivak *et al*. 2011).

This has led to most of the research in the last decade being dedicated to establishing the mechanisms and effects of most insecticides on honey bees. Although some of the aspects around insecticide and honey bee health are still poorly understood, at least the much needed awareness and education on the matter has come to light. Hence the subsequent temporary bans in most European countries on several nicotinoids implicated (McGrath 2014). Those lobbying against the use of various neonicotinoids continue globally – although companies are also not giving up on the fight to continue production and trade.

1.3.3 Hive predation, theft and vandalism

Hive predation, theft and vandalism are very common in beekeeping. Predation is primarily due to Honey badgers (*Mellivora capensis*) and incidentally from Baboons (Guy 1972; Begg & Begg 2002). Theft and vandalism by humans is common and on the increase in most parts of the world (Taylor 2000; Rust 2004; Eveleth 2013). At times, damages amount to exorbitant amounts of money. Even though beekeepers put extra protective measures in place to secure and track hives, losses are still prevalent (Johannsmeier 2001; Hall 2010). These acts do not only threaten the viability of honey bee populations for beekeeping, but discourages beekeepers to keep bees in certain areas. Often these are areas with ample quality forage critical for honey production and the vitality of colonies used for crop pollination. In this study, I document the extent and implications of hive theft and vandalism across the country - a first for South Africa at this level.

1.4 Securing forage safeguards managed honey bees

Honey bees need forage to survive and by increasing the availability and access to forage resources also benefits other insect pollinators (Gruver & Gruver 2006). Carreck & Williams (1997) postulate natural and semi-natural habitats to be good foraging areas for honey bees (including hedgerows and field margins). Furthermore, flowering plants in non-cropped farmlands can help restore and increase habitat for non-managed (wild) pollinators. In addition, a review on studies conducted in the United States, Switzerland and some European countries concur that non-cropped agricultural lands are well suited to support both wild and managed pollinators, and that semi-natural habits adjacent to farmlands should be preserved for pollinator forage resources (Decourtye *et al*. 2010). But in countries such as South Africa, it is becoming extremely difficult to find or secure such areas exclusively for honey bee habitat and forage due to various landscape activities (i.e. property developments).

There have been a few ideas and suggestions, mostly pointing at “bee friendly plants” or promoting “bee friendly gardens” (see Gruver & Gruver 2006; Costa 2008; Kellison 2009). It is believed that these efforts will contribute towards improving forage resources for honey bees and other native pollinators and in turn, their health and sustainability. As easy as this may sound, Gruver & Gruver (2006) raise concerns on a number of aspects to be taken into account when the issue of planting bee forage is raised. They include, amongst others: 1) which plants to plant (based on nectar and pollen quantity and quality), 2) location and space available, 3) which plants will provide forage faster, as well as 4) environmental conditions. Donovan (1980) also highlights the importance of non-native crop plants as good bee forage. For example, introduced crop plants such as clovers are great honey crops in countries like New Zealand. Huryn & Moller (1995) also depict some exotic weed species to be important source of both nectar and pollen for honey bees.

Eucalyptus always comes to mind when exotic bee forage is mentioned, particularly in African countries. In countries such as Cameroon, Mozambique, the Rodriguez Islands and New Guinea (D'Albore & Piatti 2004), Israel (Keasar & Shmida 2009) and Ethiopia (ESAP 2006), invasive Eucalyptus species make up important plant groups of honey bee forage. South Africa is also not an exception. Allsopp and Cherry (2004) carried out an assessment to determine the impact that the removal of several Eucalyptus (gums) species would have on the bee and agricultural industries in the Western Cape. The report covered aspects such as the invasiveness and threats posed by these species, but the main focus was on the importance of gums in the Western Cape beekeeping industry. Gums were found to be critical in the bee industry, as gum nectar is available at times when no other natural nectar is available (Johannsmeier 2005). Turpie *et al*. (2003) also stresses the fact that a major portion of summer bee forage is exclusively provided by gums, while fynbos vegetation provides forage for most winter months. The emphasis on the importance of gums to the beekeeping industry is also shared by Johannsmeier (1994), who recognizes gums for their dependability (regular flowering, constant nectar secretion and pollen production).

In context of maintaining healthy honey bee populations, it is clear that diverse forage sites are essential. However, compounding uncertainties on how securing adequately viable sites can be achieved cannot be ignored – particularly when the pressure to supply thousands of manged hives for crop pollination is mounting. For South Africa, the situation is best exemplified by the debate and uncertainty surrounding several species of Eucalyptus and their degree of importance for beekeepers, and their perceived invasive threat status by WfW. As a part of an ongoing debate on securing honey bee forage, I formulate the theme for this study around the importance of forage for various beekeeping practices. The context of this theme is outlined in the section below, together with the objectives and scope for each chapter.

1.5 Study rationale

The two indigenous honey bee subspecies actively managed by South African beekeepers depend on both indigenous and exotic forage to meet their pollen and nectar requirements. Additionally, beekeepers who rent out managed colonies for pollination have to build-up and maintain their colonies in a healthy state to ensure delivery of an adequate pollination service. Furthermore, pollination demand is expected to increase without a required increase in pollination rental services supply. At the same time, beekeepers need to produce honey and provide pollination services, practices dependent on forage availability. Lastly, areas upon which beekeepers place their hives (apiaries at forage sites) are prone to theft and vandalism thereby lowering beekeeping potential in that area irrespective of the actual forage quality. Previous research on forage use in South Africa, representing only the Western Cape Province, suggests gums are the country's major forage source. There is little evidence for the use of other forage species, let alone their importance with respect to different beekeeping practices.

The likely impact of a shortage in good quality forage (e.g. *Eucalyptus* trees) has been investigated for the Western Cape Province (Allsopp & Cherry 2004), but there is little known about potential consequences of forage shortages in other provinces. A recent study by Hutton-Squire (2014) covers historic and proportions of various forage uses across South Africa, but little is still know about the significance of various forage sources for the respective beekeeping practices. For example, *Eucalyptus* has been a much spoken about forage source with respect to its importance for producing a honey crop, but concrete evidence exists only for the Western Cape (Allsopp & Cherry 2004; Conradie & Nortjé 2008; Mouton 2011; de Lange *et al*. 2013). Other information pertaining to the importance of forage sources for colony maintenance and swarm trapping is also largely limited to the Western Cape (Mouton 2011; de Lange *et al*. 2013).

1.6 Thesis objective and chapter outline

1.6.1 Thesis objective

The beekeeping industry in South Africa is faced with multiple challenges, of which most are documented in the National Agricultural Marketing Council (NAMC) Report of 2008. The NAMC Report is a Section 7 investigation into the Beekeeping Industry of South Africa commissioned by the Minister of Agriculture following the concerns regarding the productivity and operations of the industry at the Bee Conference in 2006. The beekeeping industry is said to have great potential for growth and economic upliftment. However, the lack of information around key aspects such as forage use patterns and their importance – based on the percentage of colonies supported; the use of managed colonies for crop pollination; and the status of hive theft and vandalism are major concerns. These aspects are of importance to explore if we are to understand various needs for managed honey bees and subsequent practices.

Therefore, this thesis aims to: 1) capture and outline the status of the beekeeping industry in South Africa – Chapter 3; and 2) document forage use patterns and their importance for various beekeeping practices (i.e. honey production – Chapter 4, crop pollination – Chapter 5, swarm trapping and colony maintenance – Chapter 6). This is done for all nine South African provinces. The aspect of pollination supply and demand is also addressed by detailing estimates of pollination shortages using current and future production area projections for pollinator dependent crops and their pollination requirements (i.e. hives per hector) – Chapter 5. Hive theft and vandalism are other concerns to the beekeeping industry, and I will in this study capture and document the extent and implications of the two activities in relations to beekeeping (Chapter 7). The ultimate aim of my thesis is to contribute to the knowledge of forage use for beekeeping practices in South Africa, in order to provide a practical understanding that can support future planning and decision making relating to the planting and promotion of bee forage plants. I base my assessments and investigations on the chapter objectives outlined below. Each chapter addresses its own set of questions related to a specific beekeeping aspect which are independently answered and discussed before providing an overall synthesis of the thesis.

1.6.2 Thesis chapter outline

Chapter 2: The use of questionnaire surveys for the study: Forage Use and Hive Theft and Vandalism beekeeper questionnaire surveys. This study is not the first in South Africa to make use of a questionnaire survey to capture beekeeping demographics, practices and concerns (see Fletcher & Johannsmeier 1978; van der Merwe & Eloff 1995; Allsopp & Cherry 2004; NAMC Report 2008; Conradie and Nortjé 2008; Mouton 2011). In all these studies there were limitations and challenges, the most prominent being the low response rate and improper completions of questionnaires that results in most questionnaires being discarded.

In this chapter I explain why I chose to use beekeeper questionnaires for this study, what response rate was and what it means, and also what information was gathered for respective chapters of the thesis. I also unpack the challenges and limitations encountered in designing and distributing the questionnaires.

Chapter 3: Current status of beekeeping in South Africa: a synopsis from opinion based questions of the forage use survey. This chapter deals with beekeepers opinions on the current status of beekeeping in South Africa and the potential threats facing their industry. These were specifically based on responses to questions asked in Section D of the forage use survey. Therefore, in this chapter I aim to capture concerns relating to beekeeping in South Africa. I further compare these concerns to those initially outlined in the NAMC Report (2008) to determine whether similar concerns still persist or if new ones are experienced. By doing this, I will have an indication as to whether any of the previous concerns have been address by the government or respective beekeeping institutions.

Chapter 4: Forage use for honey production in the South African beekeeping industry. Honey bees forage on various plants for nectar in order to make honey which they store as their primary food source (Johannsmeier 2001). Honey crop plants are not well documented for all South African Provinces, but Eucalyptus is described as the most important honey crop for the Western Cape Province (Johannsmeier 1994; Allsopp & Cherry 2004; Mouton 2011). In this chapter, I document various honey crop plants across the nine South Africa Provinces to determine if the importance of Eucalyptus for honey production is similar to that of the Western Cape Province. I further outline the importance of each honey crop based on the percentage of colonies they support at a given time. The different areas used to access various honey crops are also captured.

Chapter 5: The use of managed honey bee for pollination services in South Africa: the supply versus the demand. Globally, the practice of renting honey bee hives to pollinate crops is well established (McGregor 1976; Allsopp *et al*. 2008; Calderone 2012). At the same time, the supply and demand of hives for crop pollination thoroughly interrogated to due insufficient data (Breeze *et al*. 2014). In South Africa, managed honey bees are essential for pollination of most orchard crops (e.g. apples, pears, peaches and plums) (FAO 2007;

Allsopp *et al*. 2008). In fact, commercial honey bees are said to pollinate roughly 26 crops in the deciduous fruit industry in the Western Cape Province (Allsopp & Cherry 2004). However, the extent at which manged pollinators manged honey bees are used for pollination in other provinces is not known, so is the currently hive supply to these areas. Also, forage that support hives during the pollination period and the importance thereof, has not been documented. Thus in this Chapter 5, I aim to gather information on the past and current production areas (in hectares), and future production projections for different crops known to depend on honey bee pollination as well as stocking rates per hectare. Here, I expect the pollination demand and supply to increase with the increase in production area, vice versa (Breeze *et al*. 2014). Since honey bees are known to forage within their immediate and extended vicinity (Corbet 1995; Carreck & Williams 1997), I expect forage use during pollination to be comprised of crops and non-crops (e.g. indigenous genera) with the most important forage being crops as they are in the immediate vicinity.

Chapter 6: Colony maintenance and swarm trapping: unrecognised forage use ecosystem services for managed honey bees. Honey bees require good adequate forage throughout the year to maintain colony productivity and good health (Bohan *et al*. 2005). At the same time, unforeseen events (i.e. harsh weather conditions), diseases, pests, pesticide use and pollination stress result in colony losses annually (see vanEngelsdorp & Meixner 2010). In South Africa, beekeepers rely on different forage resources to maintain their colonies, as well as to trap wild swarms during good nectar and pollen flow periods (i.e. spring and summer months) to replace colonies lost (Johannsmeier 2001; Mouton 2011). In the Western Cape Province, Mouton (2011) has successfully illustrated how beekeepers benefit from wild swarms by trapping at least 20 % of their colonies from the wild colonies each year. These are trapped on different forage sources (e.g. canola and Eucalyptus). Based on this previous work, I aim to test if swarm trapping is the most prevalent method of replenishing colonies in all nine provinces compared to other methods (i.e. hive splitting, the purchasing of new colonies and swarm removal). Different forage that supports this practice is also compared and their importance determined based on the percentage of colonies trapped per forage source. For colony maintenance, previous studies (Turpie *et al*. 2003; Johannsmeier 2001; Allsopp & Cherry 2004; Hutton-Squire 2014) indicate a combination of both exotic and indigenous to be of importance for this practice. Here, I expect similar findings to that of these studies in terms forage use, but a variation in their importance based on the percentage of colonies supported by each forage category, type and source.

Chapter 7: Theft and vandalism of managed colonies in the South African beekeeping industry. Apiary sites for managed honey bees are different across the landscape. That is in agricultural, natural and semi-natural (degraded) areas. A common threat to colonies in these landscapes is theft and vandalism, an often underestimated threat to beekeeping practices (NAMC Report 2008). At the same time, damage and loss resulting from theft and vandalism is unclear. Thus in this Chapter 7, I aim to document, categorise and compare losses relating to different forms of hive theft and vandalism, and also relate these to apiary position and visibility. I also report on various methods used by beekeepers to prevent theft and vandalism. By doing this, I will be able to assess the most prevalent form of colonies loss in relation to theft and vandalism at landscape level and the influence of visibility.

Chapter 8: General discussion. Here I discuss key findings from chapters 3-7. I place emphasis on the choice of using questionnaires to gather relevant data and illustrate how different forage is indeed the backbone for various beekeeping practices, including supporting pollination services – whereas theft and vandalism remains a threat to the different practices. In this chapter, I also suggest some key activities that relevant stakeholders can make adopt in conserving the currently available forage, promoting as well as well and enhancing forage sources.

1.6.3 Addressing the aims of each chapter

For this purpose, I use three (3) different questionnaires (Appendix A, B and D). Respective sections in these questionnaires are used to address relevant questions for each of the chapters. A detailed outline on these sections is provided in Chapter 2. In Summary, Section A of Appendix A and B (Question 5) gave account of the total number of colonies owned by beekeepers. These were used to report on the response rate and impact of questionnaires in Chapter 2. For Appendix A in particular, these numbers were further used to calculate the percentages of colonies supported by respective forage sources given in Section E of the very same questionnaire – therefore contributing to the importance of each forage species for honey production (Chapter 4), forage use during pollination (Chapter 5) and forage use for colony maintenance as well as swarm trapping (Chapter 6). Section B of Appendix A gave account of crops pollinated by managed honey bees, by percentage, and this contributed to Chapter 5. Section C of Appendix A captured average (in percentage) annual colony losses and respective methods used to make for losses. The replenishment rate was also captured in percentage. Section C of Appendix A gathered opinion based information used in Chapter 3 to report on the status of beekeeping in South Africa. Section D of Appendix A was used in Chapter 3 to give a synopsis on the status of beekeeping in South Africa. Section E of Appendix A (in table form) outlined predetermined forage known to be of beekeeping importance and also gave respondents additional space for their own additions. Here respondents gave account of how they use respective forage sources in relation to their beekeeping practices. The bloom period was stated in months and localities of forage access given. Information gathered in this section contributed to Chapters 4, 5 and 6. For Appendix B, which constituted information used in Chapter 7, not all questions were used due to their incompleteness for the responses given. More detail on the questions used is given in the Chapter. Similarly, the decision not to use Appendix D is also given in Chapter 5.

1.7 References

Aizen, M.A., Garibaldi, L.A., Cunningham, S.A. and Klein, A.M. 2009. How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. *Annals of Botany* 103: 1579-1588.

Aizen, M.A., Garibaldi, L.A., Cunningham, S.A. and Klein, A.M. 2008. Long-term global trends in crop yield and production reveal no current pollination shortage but increasing pollinator dependency. *Current Biology* 18: 1572-1575.

Alaux, C., Ducloz, F., Crauser, D. and Le Conte, Y. 2010. Diet effects on honey bee immunocompetence. *Biology Letters* 6:562-565.

Aliouane, Y., El Hassani, A.K. Gary, V., Armenguad, C., Lambin, M. and Gauthier, M. 2009. Subchronic exposure of honey bees to sublethal doses of pesticides. *Environmental Toxicology and Chemistry* 28(1): 113-122.

Allsopp, M.H. and Cherry, M. 2004. An assessment of the impact on the Bee and Agricultural industries in the Western Cape of the clearing of certain Eucalyptus species using questionnaire survey data. Pretoria (South Africa): National Government of the Republic of South Africa, Department of Water Affairs, Internal Final Report.

Allsopp, M.H. 2006. Analysis of Varroa destructor infestation of Southern African honey bee populations. MSc Dissertation, University of Pretoria, Pretoria.

Allsopp, M.H., de Lange, W.J. and Veldtman, R. 2008. Valuing Insect Pollination Services with Cost of Replacement. *PLoS ONE* 3: 1-8.

Anderson, D.L. and Trueman, J.W.H. 2000. *Varroa jacobsoni* (Acari: Varroidae) is more than one species. *Experimental and Applied Acarology* 24: 165-189.

Anderson, R.H. 1977. South African Beekeeping Census 1974/75. *South African Bee Journal* 49:7-20.

Aston, D. and Bucknall, S. 2004. Plants and honey bees: their relationships. Northern Bee Books, Hebden Bridge, UK.

Begg, K. and Begg, C. 2002. The conflict between beekeepers and honey badgers in South Africa: A Western Cape perspective. *The Open Country* N0 4 (Summer 2002): 25-36.

Beekman, M. and Ratnieks, F.L.W. 2000. Long-range foraging by the honey-bee, *Apis mellifera* L. *Functional Ecology* 14(4): 490-496.

Biesmeijer, J.C., Roberts, S.P.M., Reemer, M., Ohlemueller, R., Edwards, M., Peeters, T., Schaffers, A.P., Potts, S.G., Kleukers, R., Thomas, C.D., Settele, J. and Kunin, W.E. 2006. Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science* 313: 351-354.

Bilisik, A., Cakmak, I., and Bicakci, A. 2008. Seasonal variation of collected pollen loads of honey bees (*Apis mellifera* L. *anatoliaca*). *Grana* 47(1): 70-77.

Binns, A.J., Illgner, P.M. and Nel, E.L. 2001.Water Shortage, Deforestation and Development; South Africa’s Working for Water Programme. *Land Degradation and Development* 12: 341-355.

Bohan, D.A., Boffey, C.W.H., Brooks, D.R., Clark, S.J., Dewar, A.M., Firbank, L.G., Haughton, A.J., Hawes, C., Heard, M.S., May, M.J., Osborne, J.L., Perry, J.N., Rothery, P., Roy, D.B., Scott, R.J., Squire, G.R., Woiwod, I.P. and Champion, G.T. 2005. Effects on weed and invertebrate abundance and diversity of herbicide management in genetically modified herbicide-tolerant winter-sown oilseed rape. *Proceedings of the Royal Society of London* B 272: 463-474.

Brown, M.J.F. and Paxton, R.J. 2009. The conservation of bees: a global perspective. *A*pidologie 40: 410–416.

Breeze, T., Vaissière, B.E., Bommarco, R., Petanidou, T., Seraphides, N., Kozák, L., et al. 2014. Agricultural policies exacerbate honey bee pollination service supply-demand mismatches across Europe. *PLoS One* 9(1): e82996.

Calderone, N.W. 2012. Insect pollinated crops, insect pollinators and US agriculture: Trend analysis of aggregate data for the period 1992-2009. *PLos ONE* 7(5): e37235.

Carreck N.L. and Williams I.H. 1997. Observations on two commercial flower mixtures as food sources for beneficial insects in the UK. *The Journal of Agricultural Science* 128: 397-403.

Chauzat, M.-P., Carpentier, P., Martel, A.-C., Bougeard, S., Cougoule, N., Porta, P., Lachaize, J., Madec, F., Aubert, M. and Faucon, J.-P. 2009. Influence of pesticide residues on honey bee (Hymenoptera: Apidae) colony health in France. Environ. *Entomology* 38: 514-523.

Charles, H. and Dukes, J.S. 2006. Impacts of invasive species on ecosystem services in ecological studies. In: Nentwig, W. (Ed). Biological invasions, Vol 93. Springer, Heidelberg.

Clark, P.L. 2012. Tales of an African Beekeeper: reflections on bees and beekeeping. ISBN: 1469966719.

Conradie, B. and Nortjé, B. 2008. Survey of beekeeping in South Africa. Centre for Social Science Research. Social Surveys Unit. CSSR Working Paper No. 221.

Corbet S.A. 1995. Insects, plants and succession: advantages of long-term set-aside. *Agriculture Ecosystems and Environment* 55: 61-67.

Costa, R.C. 2008. Bee Gardening in Maryland: Providing Forage Plants for Honey Bees in Maryland. Retrieved from: http://www.tonitoni.org/bee_gardening.pdf Retrieved: 19 May 2011.

Cox-Foster, D. and vanEngelsdorp, D. 2009. Solving the mystery of the disappearing bees. *Scientific America* 2009 (April): 40-47.

Cox-Foster, D.L., Conlan, S., Holmes, E.C., Palacios, G., Evans, J.D., Moran, N.A., Quan, P., Briese, T., Hornig, M., Geiser, D.M., Martinson, V., vanEngelsdorp, D., Kalkstein, A.L., Drysdale, A., Hui, J., Zhai, J., Cui, L., Hutchison, S.K., Simons, J.F., Egholm, M., Pettis, J.S. and Lipkin, W.I. 2007. A metagenomic survey of microbes in honey bee colony collapse disorder. Science 318: 283-287.

Crane, E. 1992. The world's beekeeping – past and present. In: Graham, J.M. (Ed). The hive and the honey bee. Dadant & Sons, Hamilton, Illinios.

Crane, E. 1983. The archaeology of beekeeping. Duckworth, London, United Kingdom.

de Lange, W.J., Veldtman, R. and Allsopp, M.H. 2013. Valuation of pollinator forage services provided by Eucalyptus cladocalyx. *Journal of Environmental Management* 125: 12-18.

Decourtye, A., Mader, E. and Desneux, N. 2010. Landscape enhancement of floral resources for honey bees in agro-ecosystems. *Apidologie* 41: 264-277.

Desneux, N., Decourtye, A. and Delpuech, J.-M. 2007. The sublethal effects of pesticides on beneficial arthropods. *Annual Review of Entomology* 52: 81-106.

De Jong, D. 1997. Mites: Varroa and other parasites of brood. In: Morse, R.A. and Flottum, K. (Eds.), Honey Bee Pests, Predators and Diseases. A.I. Root Company,Medina.

Dietemann, V., Pirk, C.W.W. and Crewe, R. 2009. Is there a need for conservation of honey bees in Africa? *Apidologie* 40: 285-295.

du Preez, F.M. 2010. A history of bees and beekeeping in South Africa. Office 444 Govan Mbeki Avenue, Port Elizabeth, South Africa.

Donovan, B.J. 1980. Interactions between native and introduced bees in New Zealand. *New Zealand Journal of Ecology* 3: 104-116.

D'Albore, R.G. and Piatti, G.C. 2004. Bee forage species in some tropical Countries (Cameroon, Mozambique, Rodriguez Islands and New Guinea): identification by honey pollen analysis. *Annali della Facoltà di Agraria - Università di Perugia* 55: 293-305.

Eischen, F.A., Graham, R.H. and Cox, R. 2005. Regional distribution of Paenibacillus larvae subspecies larvae, the causative organism of American foulbrood, in honey bee colonies of the Western United States. *Journal of Economic Entomology* 98: 1087-1093.

Ellis, J.D., Munn, P.A. 2005. The worldwide health status of honey bees. *Bee World* 86: 88-101.

ESAP. 2006. Institutional arrangements and challenges in market-oriented livestock agriculture in Ethiopia. Proceedings of the 14th annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia.

Eveleth, R. 2013. Honey bee Theft Is on the Rise. Retrieved from: http://blogs.smithsonianmag.com/smartnews/2013/07/as-times-get-tough-honey bee-theft-is-on-the-rise/ Retrieved: 26 November 2013.

FAO. 2009. Bees and their role in forest livelihoods: a guide to the services provided by bees and the sustainable harvesting, processing and marketing of their products. Rome, Italy.

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

Fletcher, D.J.C. and Johannsmeier, M.F. 1978. The status of beekeeping in South Africa. *South African Bee Journal* 50: 5-20.

Fries, I. 1997. Protozoa. In: Morse, R.A., Flottum, K. (Eds.), Honey Bee Pests, Predators and Diseases. A.I. Root Company, Medina.

Fries, I., Feng, F., da Silva, A., Slemenda, S.B. and Pieniazek, N.J. 1996. *Nosema ceranae* n. sp. (Microspora, Nosematidae), morphological and molecular characterization of a microsporidian parasite of the Asian honey bee Apis cerana (Hymenoptera, Apidae). *European Journal of Protistology* 32: 356-365.

Gallai, N., Salles, J.M., Settele, J., and Vaissicre, B.E. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics* 68: 810-821.

Genersch, E. 2010. Honey bee pathology: current threats to honey bees and beekeeping. *Applied Microbiology Microtechnology* 87: 87-97.

Genersch, E., Forsgren, E., Pentikäinen, J., Ashiralieva, A., Rauch, S., Kilwinski, J. and Fries, I. 2006. Reclassification of Paenibacillus larvae subsp. Pulvifaciens and Paenibacillus larvae subsp. larvae as Paenibacillus larvae without subspecies differentiation. *International Journal of Systematic and Evolutionary Microbiology* 56: 501-511.

Gerald, F. and Combs Jr. A. 1972. The engorgement of swarming worker honey bees. *Journal of Apicultural Research* 11 (3): 121-128.

Gilliam, M. 1986. Infectivity and survival of the chalkbrood pathogen Ascosphaera apis in colonies of honey bees Apis mellifera. *Apidologie* 17: 93-100.

Goulson, D., Hanley, M.E., Darvill, B., Ellis, J.S. and Knight, M.E. 2005. Causes of rarity in bumblebees. *Biological Conservation* 122: 1-8.

Gruver, A. and Gruver, B. 2006. Providing Bee Forage.

Retrieved from: http://www.msbeea.org/sub/ProvidingBeeForage.pdf Retrieved: 12 May 2011.

Guy, R.D. 1972. The honey hunters of southern Africa. *Bee Word* 53(4): 159-166.

Hall, A. 2010. Beekeepers use tracking systems as hive thefts rise. Retrieved from: http://www.telegraph.co.uk/news/worldnews/europe/germany/7771634/Beekeepers-use-tracking-systems-as-hive-thefts-rise.html Retrieved: 03 November 2013.

Huryn, V.B. and Moller, H. 1995. An assessment of the contribution of honey bees (Apis melifera) to weed production In New Zealand protected areas. *New Zealand Journal of Ecology* 19: 111-122.

Hepburn, H.R. and Radloff, S.E. 1998. Honey bees of Africa. Springer, New York, USA.

Johannsmeier, M.F. 2001. Beekeeping in South Africa. Plant Protection Handbook No. 14, Agricultural Research Council, Pretoria.

Higes, M., Martín-Hernández, R., Botías, C., Bailón, E.G., González-Porto, A.V., Barrios, L., del Nozal, D.J., Bernal, J.L., Jiménez, J.J., Palencia, P.G. and Meana, A. 2008. How natural infection by *Nosema ceranae* causes honey bee colony collapse. *Environmental Microbiology* 10: 2659-2668.

Hutton-Squire, J.P. 2014. Historical Relationship of the Honey bee (Apis mellifera) and its forage; and the current state of Beekeeping within South Africa. MSc Dissertation, University of Stellenbosch, Stellenbosch.

Johannsmeier, M.F. 2005. BEEPLANTS of the South-Western Cape. Nectar and pollen sources of honey bees (revised and expanded). Plant Protection Research Institute Handbook No. 17, Agricultural Research Council, Pretoria.

Johannsmeier, M.F. 2001. Beekeeping in South Africa. Plant Protection Handbook No. 14, Agricultural Research Council, Pretoria.

Johannsmeier, M. F. 1994. Beekeeping and Forestry in South Africa. In South African Forestry Handbook 1994, Ed. H. A. van der Sijde. The South African Institute of Forestry, Pretoria.

Johnson, R. 2010. Honey Bee Colony Collapse Disorder. Congressional Research Service, CRS Report for Congress, RL33938.

Kearns, C.A. and Inouye, D.W. 1997. Pollinators, flowering plants and conservation biology: much remains to be learned about pollinators and plants. *BioScience* 47 (5): 297-307.

Keasar, T. and Shmida, A. 2009. An evaluation of Israeli forestry trees and shrubs as potential forage plants for bees. *Israel Journal of Plant Sciences* 57: 49-64.

Kellison, K. 2009. RE: Habitat for Managed and Native Pollinators as Priority Resource Concern for California CStP. Retrieved from: http://pfspbees.org Retrieved: 09 May 2011.

Kevan, P.G. 1999. Pollinators as bioindicators of the state of the environment: species, activity and diversity. *Agriculture, Ecosystems and Environment* 74: 373-393.

Klein, A.M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I, Cunningham, S.A., Kremen, C. and Tscharntke, T. 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society* 274: 303-313.

Kremen, C., Williams, N.M., Aizen, M.A., Gemmill-Herren, B., LeBuhn, G., Minckley, R., Packer, L., Potts, S.G., Roulston, T., Steffan-Dewenter, I., Vázquez, D.P., Winfree, R., Adams, L., Crone, E.E., Greenleaf, S.S., Keitt, T.H., Klein, A.M., Regetz, J., and Ricketts, T.H. 2007. Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. *Ecology Letters* 10: 299-314.

Levy, S. 2011. What's best for bees. *Nature* 479: 164-165.

McGrath, P.F. 2014. Politics meets Science: The case of neonicotinoid insecticides in Europe. SAPIENS 7(7.1). Retrieved from: https://sapiens.revues.org/1648 Retrieved: 08 June 2016.

McGregor, S.E. 1976. Insect Pollination of Cultivated Crop Plants, U.S.D.A. Handbook 496. Washington: U.S. Department of Agriculture, Agricultural Research Service.

Morse, R.A. and Calderone, N.W. 2000. The value of honey bees as pollinators of U.S. crops in 2000. *Bee Culture* 128: 1-14.

Morse, R.A. 1991. Bees forever. *Trends in Ecology & Evolution* 6(10): 337-338.

Morse, R.A. and Flottum, K. 1997. (Eds.) Honey Bee Pests, Predators, and Diseases. A.I. Root Company, Medina, Ohio, USA.

Mouton, M. 2011. Significance of Direct and Indirect Pollination Ecosystem Services to the Apple Industry in the Western Cape of South Africa. MSc Dissertation, Stellenbosch University, Stellenbosch.

NAMC Report. 2008. 3rd Draft Report. A section 7 committee investigation. The South African Beekeeping Industry. Pretoria, South Africa.

Naug D. 2009. Nutritional stress due to habitat loss may explain recent honey bee colony collapses. Biological Conservation 142: 2369-2372.

Neumann, P. and Carreck, N.L. 2010. Honey bee colony losses. *Journal of Apicultural Research* 49(1):1-6.

Page, R.E. 1998. Blessing or curse? Varroa mite impacts Africanized bee spread and beekeeping. *California Agriculture* 52:9-13.

Pankiw, T., Huang, Z., Winston, M.L. and Robinson, G.E. 1998. Queen mandibular gland pheromone influences worker honey bee (*Apis mellifera* L.) foraging ontogeny and juvenile hormone titers. *Journal of Insect Physiology* 44(7-8): 685-692.

Pimentel, D., Zuniga, R. and Morrison, D. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273-288.

Potts, S.G, Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O. and Kunin, W.E. 2010. Global pollinator declines: trends, impacts and drivers. *Trends in Ecology and Evolution* 25 (6): 345-353.

Proctor, M., Yeo, P. and Lack, A. 1996. The natural history of pollination. HarperCollins Publishers, London, UK.

Rust, S. 2004. The beehive protection cage. *South African Bee Journal* 76: 90-92.

Rosenkranz, P., Aumeier, P. and Ziegelmann, B. 2010. Biology and control of Varroa destructor. *Journal of Invertebrate Pathology* 103: S96-S119.

Sagili, R.R., and Burgett, D.M. 2011. Evaluating honey bee colonies for pollination: A guide for commercial growers and beekeepers. A Pacific Northwest Extension Publication, PNW 623.

Schmidt, J.O. and Thoenes, S.C. 1987. Swarm traps for survey and control of Africanized honey bees. *Bulletin of the Entomological Society of America* 33 (3): 155-158.

Shen, M., Yang, X., Cox-Foster, D. and Cui, L. 2005. The role of varroa mites in infections of Kashmir bee virus (KBV) and deformed wing virus (DWV) in honey bees. *Virology* 342: 141-149.

Smith, F.G. 1960. Comb foundation: its use for African bees. *Bee World* 41(9): 235-240.

Somerville, D. 2000. Honey bee nutrition and supplementary feeding. AGNOTE, NSW Agriculture. DAI/178: 1-8.

Spivak, M., Mader, E., Vaughan, M. and Eullis Jr, N.H. 2011. The plight of the bees. *Environmental Science and Technology* 45:34-38.

Taylor, M. 2000. Container beekeeping. *South African Bee Journal* 72: 32-33.

Turpie, J. K., Heydenrych, B. J. and Lamberth S. J. 2003. Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation strategies. *Biological Conservation* 112: 233-251.

Van der Merwe, W.J. and Eloff, P.J. 1995. Byeboerdery in Wes-Kaapland. *South African Bee Journal* 67: 105-114.

vanEngelsdorp, D. and Meixner, M.D. 2010. A historic review of manged honey bee populations in Europe and the United States and the factors that may affect them. *Journal of Invertebrate Pathology* 103: S80-S95.

van Engelsdorp D, Evans J.D., Saegerman C., Mullin C., Haubruge E., Kim B., Nguyen,B.K., Frazier, M., Frazier, J., Cox-Foster, D., Chen, Y. Underwood, R., Tarpy, D.R. and Pettis, J.S. 2009. Colony Collapse Disorder: A Descriptive Study. *PLoS ONE* 4: e6481.

vanEngelsdorp, D. Hayes, J. Underwood, R.M. and Pettis, J. 2008. A survey of honey bee colony losses in the U.S., Fall 2007 to Spring 2008. *PLoS ONE* 3(12): e4071.

Williams, P. 2005. Does specialization explain rarity and decline British bumblebees? - A response to Goulson et al. *Biological Conservation* 122: 33-43.

Winston, M.L. 1991. The biology of the honey bee. Harvard University Press.

Chapter 2

The use of questionnaire surveys for the study: Forage Use and Hive Theft and Vandalism beekeeper questionnaire surveys

2.1 Bee forage initiative: the forage use beekeeper questionnaire survey

The use of beekeeper questionnaires are a common phenomenon globally. They are used to assesses, capture or document desired trends and information for various purposes. Currently, the monitoring of bee declines and factors responsible seem to be in the spotlight. Many countries have adopted the COLOSS (Prevention of honey bee COlony LOSSes) approach in the reporting of losses. COLOSS is an international, non-profit association headquartered in Bern, Switzerland and focuses on improving the well-being of bees at a global level. It comprises of various experts and student across 60 countries worldwide (COLOSS 2014). South Africa is also a signatory to this initiative.

2.1.1 Previous questionnaires in the South African beekeeping industry

In the past 30 years, there have been four questionnaire based studies done on the beekeeping industry in South Africa. These include: 1) Fletcher & Johannsmeier (1978), the results are also elaborated by Anderson (1978); 2) van der Merwe & Elloff (1995); 3) Allsopp & Cherry (2004); and 4) Conradie & Nortjé (2008). Common among the questionnaires was the documentation of the number of colonies owned by each beekeeper, forage type used and its importance, annual honey production rate (kg). At the most, pollination services rendered were asked and the economic importance thereof. The economic aspects of bee forage and consequences of bee forage loss were only addressed in Allsopp & Cherry (2004), who focused on the potential impact of Eucalyptus removal to the beekeeping and agricultural industries in the Western Cape Province.

Questionnaire dissemination modes were different and that is also well reflected in the return rate. Also, beekeepers are generally reluctant to fill in questionnaires, contributing to the poor return rate in some of the studies. The most recent survey was that of Conradie & Nortjé (2008). They mailed out 500 hardcopy questionnaires to beekeepers registered to SABIO at the time and they achieved a 22.4% response rate in which 112 completed questionnaires where returned. This survey covered an estimated 19 520 managed honey bee colonies across the country. Allsopp & Cherry (2004) also used hard copy questionnaires targeting beekeepers on SABIO's list of registered beekeepers and unlisted beekeepers. This survey obtained a response rate of 19.05% (173 response from 908 beekeepers), and covered 33 836 managed honey bee colonies in the Western Cape. In a 1995 survey conducted by van der Merwe and Elloff (1995), a questionnaire was circulated to a selected 250 beekeepers and received a 57% response rate. Fletcher & Johannsmeier (1978) were the first to send out a national survey in the beekeeping industry in 1975 and they achieved a 40.4% response rate (702 response from 1736 questionnaires released), representing a total of 60 389 managed honey bee colonies. Since the survey of Fletcher & Johannsmeier (1978), there has never been another national beekeeping industry survey of its magnitude until the Honey bee Forage Project survey carried out in 2011/12.

This chapter explains the use of questionnaires in collating data relevant to the aims and objectives of the respective chapters. The purpose of each questionnaire is further described together with the distribution methods, response rate, data groupings and challenges encountered. The use of questionnaires had no ethical implications as no personal information (e.g. age, income levels, race etc.) were used in any of the responses or analysis. The information synthesis approach used for both questionnaires follows that of Allsopp & Cherry (2004), which did not make use of personal information for any of the results and discussions. The anonymity of the respondents (beekeepers) was communicated in a covering letter (attached as Appendix E) disseminated with the journal issue mentioned in sections 2.2.3 and 2.3.1 and presentations also mentioned in the two respective sections.

2.2 Honey bee Forage Project's forage use beekeeper questionnaire survey (Appendix A)

2.2.1 The use of the questionnaire

The primary aim of using the questionnaire was to document information on the current honey bee forage uses, as well as their importance and contribution to various beekeeping practices (i.e. honey crop). The localities at which these forage resources occur and flowering (bloom) periods were equally important to capture. Firstly, I needed to know how many beekeepers are there in South Africa and how many colonies they each manage.

Furthermore, the pollination services beekeepers render as well as various methods used for colony replenishment needed documentation as they are poorly understood. Given an estimation of 2170 beekeepers in South Africa by the NAMC Report (2008), it was an overwhelming challenge to selectively conduct person visits for interviews to collect the desired data and document such trends. A questionnaire seemed the best logical option to use in this instance. It was concerning that we might have a poor response rate given the recent survey by Conradie & Nortjé (2008), but the use of the questionnaire was the most practical solution.

2.2.2 Questionnaire structure

A South African honey bee forage questionnaire was designed specifically for South African beekeeping industry after extensive consultation with beekeepers and several researchers in the field. Both parties had the period of September – October 2011 to give constructive criticism and inputs to the questionnaire. The questionnaire was subsequently completed and released in December 2011. It was however only circulated by the end of January 2012 due to mailing problems beyond the project's control. The questionnaire was initially given a circulation period of three months, but a low turn in rate and rifts between the industries extended the period to eight months (to September 2012). Beekeepers were guaranteed confidentiality on all their responses.

A public dissemination program, which included journal articles published in the South African Bee Journal (SABJ), presentations at Beekeeper Association meetings and a general awareness campaign preceded the release of the questionnaire, prevailing on beekeepers nationally to complete the questionnaire, and appealing to them to make contact if they did not receive the questionnaire, or if they had any queries or questions. This program was also used to explicitly explain the purpose of the study, as well as assure all beekeepers that the questionnaire was a completely confidential exercise, whereby no individual questionnaire information would be released or published in any form. Beekeepers were further advised to state their localities of forage as closest town(s) or region(s) as opposed to giving the exact location of their apiary sites.

The questionnaire was designed to be as "user friendly" as possible whilst still being able to gather the required information. Sections of the questionnaire were outline as follows:

- **Section A:** Here personal information and contact details of the beekeeper, home base indicated as nearest town, years of beekeeping experience and number of colonies managed were required.
- **Section B:** The beekeeper had to indicate the percentage of colonies used to render commercial (paid) pollination only. This percentage is the portion of the total colonies indicated in Section A. Agricultural crop groups (8) are also suggested for indication of the type of pollination offered. Again, an average percentage had to be given with the total amounting to 100% for selected crops. Beekeepers had an option to list any additional crops not provided on the suggestion list.
- **Section C:** In this section, beekeepers were expected to indicate the average percentage of their colonies (listed in Section A) lost annually. Causes leading to losses are not accommodated for here. Four different methods recognised for colony replacement are listed for beekeepers to indicate which is applicable to them and the percentage of colonies recovered. The total percentage of any methods selected added up to a 100%.
- **Section D:** Opinion based questions in this section were designed to gain insight into the beekeeping industry status and perception. Beekeepers had to answer all questions as honest as possible to the best of their abilities. Results of this section are presented in chapter 3.
- **Section E:** Here beekeepers had to indicate the type of forage used for their beekeeping operations. In particular, beekeepers indicated the value (as a percentage of their total forage resources) for each forage type in terms of various beekeeping practices. These were honey produced (honey crops), preparing colonies for commercial pollination (pollination), sustaining colonies for the entire year (colony build-up), and the trapping of swarms (swarm trapping). Percentages for each category added up to a 100 %. Flowering (bloom) periods of each forage type was indicated by months of the year and given as 1 (Jan) to 12 (Dec). Areas or localities were forage occurred was indicated by naming the nearest town. This provided for a maximum of four (4) towns per forage type. The regional veld type

(vegetation units) such as suburban gardens or West Coast fynbos could be used to indicate forage types, if individual forage species are not known.

A list of 58 forage species was published in the questionnaire table, with seven, regional generic vegetation units listed additionally. The 58 forage species were listed in categories, namely: Eucalyptus (13); Crops (14); Trees (12); Shrubs, succulents, herbs (13); and Weeds (6). The seven regional generic vegetation units were the following: Suburban Gardens; Indigenous Forests; West Coast Fynbos/Strandveld; South Cape Strandveld; Mountain Fynbos; Karoo (including Nama and Succulent Karoo); Bushveld. These forage species were chosen based on their known status as managed honey bee forage species, used in various regions of South Africa. Each species has been listed as important forage (Johannsmeier, 2005) and was recommended by the ARC Honey bee Research Unit as a significant forage sources. The questionnaire forage species list did not discriminate against either indigenous or exotic species. At the end of the species and generic regional vegetation list an "Other" section was published, which allowed beekeepers to add forage species which they use and were not listed in the printed species list.

2.2.3 Questionnaire distribution

The questionnaire was distributed nationally and targeted all South African beekeepers, regardless of whether a professional, commercial, hobbyist or developing beekeeper. In a South African context, a professional beekeeper owns (manages) 100-7000 hives, commercial beekeeper a 100-1000, hobbyist 1-100 and a developing beekeeper 5-500 hives (NAMC Report 2008). South African beekeepers are required through legislation to be registered with a central agricultural organization (i.e. SABIO), but this requirement is often ignored by beekeepers, and has not been enforced by the State. In addition, beekeepers in South Africa have never been inspected or audited. As a result of this, no reliable database of beekeepers or beekeeping is available and data on the exact number of beekeepers does not exist. Therefore, in order to ensure the questionnaire was received and completed by as many beekeepers as possible, multiple distribution channels were used.

The forage questionnaire was distributed as a hardcopy, both in English and Afrikaans, with a postage paid return addressed envelope within the December 2011 edition of the South African Bee Journal (Volume 83 No. 4) which is a quarterly published journal that is distributed to all registered SABIO members, as well as to all other known beekeepers. Questionnaires were also distributed via two voluntary South African beekeeper email groups on the 19th January 2012. These are the BeeSAGoogleGroups (beessa@googlegroups.com) and ApicultureSA (apiculture-sa@googlegroups.com). These two email groups both have large followings and are well represented. For this purpose, beekeepers were asked to complete the questionnaires and return via email to the designated addresses.

In addition to the two discussed methods of questionnaire distribution, oral presentations were given at four provincial beekeeper association meetings, as well as at the annual SABIO BEECON (South African Bee Industry Organisation Bee Conference, Gauteng; 15 June 2012), to further promote the questionnaire. Beekeeper Association meetings attended included: 1) Southerns Beekeeping Association meeting (Gauteng; 13 April 2012); 2) KwaZulu Natal Bee Farmers Association meeting (KwaZulu Natal; 17 March 2012); 3) Eastern Highveld Beekeepers' Association meeting (Gauteng; 17 March 2012); and 4) Vhembe Beekeepers meeting (Limpopo; 22 March 2012). All presentations were met with good response and increased the response rate of the questionnaires. The final bid to ensure a good response rate was performed in the form of telephone calls made directly to known commercial beekeepers who had as yet not returned their questionnaire. In some cases, beekeepers politely declined from responding, while others were grateful for the telephonic reminder and completed and returned their questionnaires via email or postal service.

The South African Bee Journal circulated a total of 1400 hard copies. ApicultureSA and BeesSAGoogleGroups have about 340 and 270 subscribers respectively. An additional 142 questionnaires were handed out at the BEECON and beekeeper association meetings for completion. The entire survey circulations had potentially reached a total of 2152 beekeepers, although there could well have been double-to-triple postings as some beekeepers subscribed to multiple beekeeper communication media.

2.2.4 Questionnaire impact (response rate)

The survey yielded 218 beekeeper responses constituting a total of 50067 colonies for all nine provinces. The Western Cape Province (WC) recorded the highest number of colonies (23157) from 87 respondents, followed by KwaZulu-Natal (KZN) with 8448 colonies from 18 respondents. The Northern Cape Province (NC) had a record of 5562 colonies from five respondents. For the Eastern Cape (EC), 14 responses constituted 4329 colonies, while Gauteng (GP) recorded 2026 from 38 respondents and Limpopo Provinces (L) had a total of 1997 colonies from 38 respondents. Mpumalanga Province (MP) had one respondent more that the North West Province (NW), seven and six respectively, with recorded colonies amounting to 2977 and 1361 respectively. Free State Province (FS) had the lowest recording of 210 colonies from five respondents.

Similar uneven trends in managed colony numbers across provinces were also evident in previous surveys. From the study by Conradie & Nortjé (2008), the Western Cape Province had the highest number of respondents and colonies. A trend similar to that recorded in this survey. However, Allsopp & Cherry's (2004) "gum report of the Western Cape" still topped both these studies as they recorded 33386 managed colonies from 173 respondents in the Western Cape. Historically, the Western Cape Province and KwaZulu-Natal have always had a vibrant and actively participating beekeeping industry due to practices associated with honey production and crop pollination.

In terms of colony presence in other provinces, Conradie & Nortjé's (2008) survey recorded all nine provinces to have less than a thousand managed colonies each, while in this study the Free State was the only province to record less than a thousand colonies. Nationally, Fletcher & Johannsmeier (1978) were the last to record a high of 60000 actively managed colonies in South Africa. This study fell short by 16.5% of their study as it recorded 50067 colonies, although it has been over a 34 years since their study was conducted. Allsopp & Cherry (2004) estimate that there are currently 120000 actively managed colonies in South Africa, whereas *Pirk et al. (2014) argue that total managed colonies in South Africa amount to 100 000. Nonetheless, this study represents* 42% and 50.1% of the estimated figures respectively when compared to both estimates respectively. It is important to note that that managed colonies per province will likely vary with each survey and that the potential to keep and manage colonies in respective provinces is heavily influenced by other factors (i.e. forage availability).

The findings presented in various chapters of this study are a thorough representation of the responses obtained. The Western Cape is well represented, compared to other provinces and this is attributed to the reasons outlined above. It might also be that beekeepers in other provinces are just not willing to share or divulge information compared to those in the Western Cape, and not necessarily implying that there are no vibrant and big beekeeping practices in those provinces. Data presented in graphs, tables and maps for a particular area or province is that informed by the questionnaire. The trends (scattered or clumped) are a true reflection of data received and the activity areas within respective areas or provinces.

2.2.5 Questionnaire data grouping and analysis

The questionnaire sections cater for different chapters in this study; therefore respective data analysis is outlined in each chapter for the content applicable. The overall post-response evaluation of the survey indicated that the questionnaire was in general conscientiously and accurately answered. In some cases, however, species names when supplied where outdated, and in a few instances, critical information was omitted. As questionnaire responses were returned, the information of each completed questionnaire was entered into a series of Microsoft Excel data sheets. In some instances questionnaires were not correctly completed or information was omitted. Where possible these individual beekeepers were contacted via email or telephonically and asked for the correct information.

Questionnaires that were over 50% incomplete and beekeepers were not keen to supply the information were completely omitted from the responses. Also, questionnaires that had data missing for the table in Section E, whereby forage percentages were not given, the forage location (nearest town) not stated, and flowering periods not accounted for – these questionnaires were not considered for the forage provision (use) analysis. This was specifically for the Free State, Gauteng, KwaZulu-Natal, Limpopo and Western Cape Province. Table 2.1 below indicates how these omissions were accounted for. Forage results presented throughout the respective chapters is based on the revised total outlined in the "colonies accounted for forage use" row.

Table 2.1: Differences in colonies accounted for forage use per province.

Category	EC	FS	GP	KZN	L	MP	NC	NW	WC
Colony total	4329	210	2026	8448	1997	2977	5562	1361	23157
Colonies accounted for forage use	4329	205	1796	8446	1855	2977	5562	1361	23013
Colony difference:	**0**	**5**	**230**	**2**	**142**	**0**	**0**	**0**	**144**

The survey was not designed to accommodate a category for beekeepers to indicate whether their forage/apiary sites are fixed throughout the season/year or if they are rotational. But it evident, based of localities given, that cross boarder migration of colonies was prevalent. This meant that respective provinces experience increases or decreases of colonies at a given time period. In this instance, the Free State which has stationary colonies of 205, receives an influx of 6709 during various times of the year from Gauteng, KwaZulu-Natal and North West (Table 2.2). Other provinces with such influxes include KwaZulu-Natal, Limpopo, Mpumalanga and North West, although their influxes are much lower than that on the Free State (Table 2.2). This can be attributed to beekeeping operation size, access to forage or even the rendering of pollination services (Pirk *et al*. 2014). The summer rainfall area of the country (scutellata region) does not have colony movement restrictions as opposed to the winter rainfall region (capensis region) hence the movement of colonies in these northern parts of the country are more common (Johannsmeier 2001).

The outlined migratory colonies represent forage use for honey crop, pollination and colony build-up in respective provinces. Colony migration is common phenomenon in beekeeping due the need to access good forage (Clark 2012) and provides pollination services (Morse & Calderone 2000). For this section on migration, swarm trapping is excluded from the analysis for respective provinces they migrate to since swarms trapped in those particular areas/provinces are not considered as foraging colonies – are not taken there to access forage or used to provide pollination services. However, it should be made clear that trapped swarms do make use of the forage in that area for a certain unknown period before being moved to a desired apiary site. Total and average colonies per areas (migratory or in province) for different forage uses are presented in respective chapters of this study (e.g. Chapters 4, 5 and 6).

Table 2.2: Migratory and stationary colonies for each province.

Province	Total number of colonies	Stationary colonies	Migratory colonies	Migratory provinces (number of colonies)								
				EC	FS	GP	KZN	L	MP	NC	NW	WC
EC	4329	4304	25	-	-	-	-	-	-	-	-	25
FS	205	205	0	-	-	-	-	-	-	-	-	-
GP	1796	1090	706	-	202	-	-	193	59	-	251	-
KZN	8446	1946	6500	-	6500	-	-	-	-	-	-	-
L	1855	1855	0	-	-	-	-	-	-	-	-	-
MP	2977	2710	267	-	-	-	240	27	-	-	-	-
NC	5562	5562	0	-	-	-	-	-	-	-	-	-
NW	1361	1054	307	-	7	210	-	-	90	-	-	-
WC	23013	22938	75	-	-	-	-	-	-	75	-	-
			Total:	**-**	**6709**	**210**	**240**	**220**	**149**	**75**	**251**	**25**

Data recorded on forage use and importance was divided into two main forage categories, Indigenous and Exotic forage. The groups were further divided into sub-categories as follows (refer to Appendix B for a full list of bee forage plants compile from the survey):

- **Indigenous forage:** 1) Indigenous genera – these includes listed trees (excluding Eucalyptus), shrubs, succulents, herbs, grasses and indigenous weeds occurring within the natural (undisturbed areas) landscape; and 2) Vegetation units – commonly referred to as veldtypes or vegetation units and are presented as described by Mucina & Rutherford (2006). For the purpose of this study vegetation units are further grouped as follows: i) Bushveld; ii) Eastern Cape Thicket (Eastern Cape Bushveld, Mixed Thornveld, River bush Valley, Valley Thicket, Thicket Mosaic Fynbos); iii) Indigenous Forests (Forests, Wild Coast Remnant Forests); 3) Karoo (Karoo, Klein Karoo); iv) Namaqualand & Renosterveld (Renosterveld, Namaqualand Wild Flowers, Succulent Karoo); v) Mountain Fynbos; vi) Coastal Fynbos (Walkerbay

Fynbos, Southern Cape Strandveld, Southern Cape Fynbos) and vii) Strandveld (West Coast Fynbos/Strandveld, Sandveld Wild Flowers).

- **Exotic forage:** 1) Eucalyptus – includes formal forestry, feral and demarcated Eucalyptus plantations; 2) Agricultural crops – refers to all agricultural crops planted for commercial and non-commercial purposes; 3) Suburban plantings – these include home garden plants, suburban tree lanes, city park plants and other exotic ornamental plants; and 4) Weeds – those plants that are considered undesirable or unwanted in certain habitats/landscapes.

There were also new plants and vegetation units listed by beekeepers – these were not included in the provisional table circulated to beekeepers. In total, 43 new plants were captured (see Appendix C). Each province captured new listings except North West. The Eastern Cape accounted for eight (8) new listings, Free State one (1), Gauteng ten (10), KwaZulu-Natal and Limpopo accounted for two (2) each, Northern Cape one (1) and the western Cape 16. This indicated the diversity of forage that beekeepers depend on for their managed colonies and that there are possibly many other forage sources not captured in this survey.

2.2.6 Questionnaire challenges and limitations

The questionnaire aimed at collecting data that is currently limited or even non-existent on record in South Africa. Because beekeepers are not legislatively mandated to keep and provide (when necessary) official beekeeping records, most then prefer to keep such information to themselves. This also serves to avoid competition for forage sites and pollination contracts. Many beekeepers consider their forage usage to be a highly sensitive subject and would rather not divulge such information. As such, the questionnaire was designed so that beekeepers would not be required to divulge precise location of their apiary sites, but rather give an indication of the closest town to each site. Therefore, no exact, but closest apiary site location is captured for this study. In this way, the data could then only be divided into provincial areas, based on the closest town given.

The survey data itself was the first of its kind to be collected at this magnitude for the country. There is also little literature to support or disapprove some of the data captured through this study. For example, the Western Cape is the most comprehensively documented province in terms of pollination needs and bee forage use compared to the others. This makes it difficult to ascertain the trustworthiness level of information provided for other provinces. Also, colony numbers and different forage listed by beekeepers is considered to be correct and added to the provisional list given in Section E of the questionnaire. Statistically, comparisons of data for respective provinces or aspects of forage use were deemed not feasible due to the incomparable responses and colony numbers. As such, descriptive statistics by means of percentage and relative numbers (at times estimates) were used to best relay the findings.

Most organisations are prone to individual and political factions and the local beekeeping industry is no different. There were anti-questionnaire groups that spread doubts and negative interpretations about the survey. This led to the survey not being showcased and promoted at some beekeeper association meetings (permission was not granted for this purpose by those associations). Random e-mails and phone calls also made rounds to discourage positive response from beekeepers willing to participate. Disgruntled beekeepers formed a break away beekeeping body from SABIO, which was termed Southern African Apicultural Federation (SAAFED). This federation has since become dormant, with not much of their goals and objectives ever made public. Although not known, I assume this might have somehow hampered the survey impact and possibly lowered the response rate. However, the extension of the survey deadline might have helped in the responses obtained.

2.3 Hive theft and vandalism questionnaire survey (Appendix B)

In the past, managed hives were mostly prone to predation by honey badgers and at times baboons (Begg & Allsopp 2001; Begg & Begg 2002). However, in the last decade, hive vandalism and theft due to man has been on the rise, costing beekeepers huge sums of money to continue their beekeeping activities. Du Preez (2010) indicates that hive theft and vandalism are not new phenomenon in the South African beekeeping industry. At the same time, no accurately detailed data exists to can thoroughly quantify the impacts and implications of these acts for beekeeping across the country. Therefore, the purpose of this questionnaire was to gather the sufficient relevant information on hive theft and vandalism to address this data gap and understanding of the activity itself.

2.3.1 Questionnaire distribution

The distribution of the hive theft and vandalism questionnaire was aligned with that of the forage use survey. The design timeline, trial period and distribution method were done simultaneously. Challenges and limitations expressed in the forage use questionnaire section had similarly affected theft and vandalism questionnaire. The structure of the theft and vandalism questionnaire was different to that of the forage use questionnaire because each questionnaire had a specific purpose. Also, there were beekeepers that did not respond to both surveys. Therefore, not the same colonies belonging to the same beekeeper were always accounted for in both surveys. The structure for the theft and vandalism questionnaire was as follows:

- **Section A:** In this section personal information and contact details of the beekeeper were required, home base indicated as nearest town, years of beekeeping experience and number of colonies managed. A breakdown in terms of localities where colonies were kept was also required, as well as the percentage of colonies used for commercial pollination.
- **Section B:** Here, questions were structured to gather information on the type of theft or vandalism experienced duration (years), where (location), how the losses varied per locality, how the apiary is positioned, abandoned sites, and estimates of money spent in enforcing preventable measures to theft and vandalism.
- **Section C:** Opinion based questions asked in this section were aimed at getting the insight or perceptions of beekeepers on hive theft and vandalism. This included those responsible, the assistance provided by police and the desire to use any technological devices (means) to curb or prevent acts of theft and vandalism.

2.3.2 Questionnaire impact (response rate)

A total of 161 responses were received representing 48386 managed colonies. This survey was 57 respondents and 1681 colonies short of the results yielded by the forage use survey. The Western Cape Province had the highest number of managed colonies (23348) from 85 respondents followed by KwaZulu-Natal with 8967 colonies from 14 respondents. The Northern Cape had 4562 colonies from five responds followed by the Eastern Cape with 3999 colonies from 12 respondents. For Mpumalanga, six responses constituted 3090 colonies, while Gauteng recorded 1826 colonies from 30 respondents and North West had a total of 1290 colonies from four respondents. Limpopo had one respondent less than that of the Free State, two and three respectively, with recorded colonies amounting to 1100 and 204 respectively.

2.3.3 Questionnaire data grouping and analysis

Similarly with the forage use survey, the overall post-response evaluation of the survey indicated that the questionnaire was in general conscientiously and accurately answered. As questionnaire responses were returned, the information of each completed questionnaire was entered into a series of Microsoft Excel data sheets. In some instances questionnaires were not correctly completed or information was omitted. Where possible these individual beekeepers where contacted via email or telephonically and asked for the correct information. Questionnaires that were over 60% incomplete and beekeepers were not keen to supply the information were completely omitted from the surveys. Detailed data analysis for each section of the questionnaire is explained in the method section of chapter 7.

2.4 Reliability in response for both questionnaires

The challenges and limitation in the use of the questionnaires have been outlined in section 2.2.6, and these are not unique to my surveys. The information provided by respondents is taken to be correct, with incomplete questionnaires discarded in situations where phone call and email follow ups were unsuccessful. In this instance, there was no feasible method adopted to verify or validate the truthfulness of the questionnaire information provided by respondents. This also relates to the aim of both questionnaires in the first place – to document trends and establish level of use (and importance) of forage resource in respective provinces for various beekeeping operations. Therefore, information provided by respondents is taken to be that of their best knowledge and thus reliable. Similar approach is adopted in Allsopp & Cherry (2004) as well as Conradie & Nortjé (2008). Therefore, as the primary investigator in this study I had no control over any false nature or inconstancies therefor resulting from the information supplied by the respondents.

2.5 Department of Department of Agriculture, Forestry and Fisheries (DAFF) beekeeper registration statistics

The South African Bee Industry Organisation (SABIO), which is an organised body representing the beekeeping industry in South Africa was responsible for beekeeper registration until early 2014. The Department of Agriculture, Fisheries and Forestry has since taken over the registration of beekeepers and now oversee all compliances with regard to beekeeping practices – see chapter 3 for further details. Here, I use DAFF's registration statistics for all nine provinces to indicate the impact of my two surveys and also highlight the difficulties in getting responses from beekeepers.

Between March 2014 and March 2016, DAFF recorded a total of 1246 beekeepers constituting 79901 managed colonies (Table 2.3). However, by end January 2016, DAFF's beekeeper registration total stood at 1069 beekeepers constituting 60351 managed colonies (Table 2.3). This means that an extra 177 beekeepers were captured together with an extra 19550 colonies. This potentially means that there are still more beekeepers and colonies not captured nationally – and it would be interesting to observe how these numbers increase throughout the registration period. When comparing my two surveys with DAFF's latest recordings, DAFF captured 1028 (82.5%) and 1085 (87.1%) more beekeepers, and 29834 and 31515 more colonies than what my forage and vandalism and theft questionnaires yielded respectively.

Table 2.3: Beekeeper survey comparisons.

Province	Survey Type						Colony number difference between surveys	
	Forage Use		Vandalism & Theft		DAFF			
	Beekeepers	Colonies	Beekeepers	Colonies	Beekeepers	Colonies	Forage use versus DAFF	Vandalism & Theft versus DAFF
EC	14	4329	12	3999	87	4807	478	808
FS	5	210	3	204	41	2830	2630	2626
GP	38	2026	30	1826	252	7857	5831	7857
KZN	18	8448	14	8967	92	8396	*52	*571
L	38	1997	2	1100	85	2529	532	1429
MP	7	2977	6	3090	79	1119	*1858	*2971
NC	5	5562	5	4562	21	3317	*2245	*1245
NW	6	1361	4	1290	33	1207	*154	*83
WC	87	23157	85	23348	556	47839	24682	24491
Total	**218**	**50067**	**161**	**48386**	**1246**	**79901**	**N/A**	

*Indicates high colony number difference in favour of the forage use and vandalism and theft surveys compared to DAFF

On average, the DAFF results indicated each beekeeper to own on average far fewer colonies (64) compared to the forage use (230) and hive theft and vandalism surveys (301). Because my interest was mostly based on colony numbers (for the purpose of Chapters 4, 5 and 6 data) as opposed to beekeeper numbers, I further compared the differences in colony numbers between my surveys and that of DAFF (Table 2.3). Provincially, some provinces we much better represented but others not. In particular, my two surveys were consistently better represented for KwaZulu-Natal, Mpumalanga, Northern Cape and the North West. A possible explanation to this trend is that both my surveys captured fewer beekeepers but did get responses from those that own a high number of colonies individually (professional or commercial beekeepers) as opposed to that of DAFF's beekeeper registration that was dominated by a lot of small beekeepers as opposed to larger professional or commercial beekeepers. Hence the low number of beekeepers recorded for both my surveys, but with high colonies numbers. Either way, DAFF's records remains superior in both beekeeper and hive numbers. Subsequently, this serves as an opportunity to continuously collate national beekeeping data through the DAFF beekeeper registration process for various planning and management needs, as beekeepers seem to be more responsive and cooperative under the call of the government authority.

Another interesting observation was that the DAFF survey captured over 50% more colonies in the Western Cape and almost seven times more colonies in the Free State compared to my two surveys. In both my surveys, that of Allsopp & Cherry (20014), Conradie & Nortjé (2008) and the DAFF survey, the Western Cape Province recorded the highest number of colonies. Although it is difficult to provide exact reasons for this trend, it can be assumed that beekeepers in the Western Cape are more cooperative, active and participate extensively in various surveys. It can also imply that this province is the biggest in terms of beekeeping, which makes sense when taking into account the pollination needs and services for the fruit industry (see Allsopp *et al*. 2008; de Lange *et al*. 2013; Melin *et al*. 2014).

Conradie & Nortjé (2008) argue that estimated beekeeper and colony numbers for South Africa is highly unreliable due to inaccurate data and the reluctance of beekeepers to respond to surveys. Using various estimates, they demonstrate that beekeeper numbers could be as low as 900, while colony numbers could be as high as 300,000. Given the DAFF colony statistic presented above, the high estimated colony total is very unlikely. Besides, no survey is yet to document the more than 100,000 colonies believed to be the correct estimate of managed colonies stipulated by Allsopp & Cherry (2004) and Pirk *et al*. (2014). Therefore, different voluntary questionnaire surveys conducted will somehow always give a different account, that is either an under or overestimation of both numbers.

2.6 Conclusion

The purpose of both surveys was to gather relevant data that will be discussed in chapters 3 to 7. Unfortunately, the size composition of the beekeeping industry in South Africa is difficult to determine given the reluctance from some beekeepers to complete surveys. This was also observed in previous questionnaires. Nonetheless, the response rate achieved in this study was beyond expectation and within a desirable sample size for this notoriously difficult industry – although the effort in achieving this was more extensive. Given the survey results of DAFF, it suggests that future surveys be conducted through their beekeeper registration database. This could ensure a minimum expected response rate with the hope of increasing the tally on both beekeeper and hive numbers.

2.7 References

Allsopp, M.H., de Lange, W.J. and Veldtman, R. 2008. Valuing Insect Pollination Services with Cost of Replacement. *PLoS ONE* 3(9): e3128. doi:10.1371/journal.pone.0003128.

Allsopp, M.H. and Cherry, M. 2004. An assessment of the impact on the Bee and Agricultural industries in the Western Cape of the clearing of certain Eucalyptus species using questionnaire survey data. Pretoria (South Africa): National Government of the Republic of South Africa, Department of Water Affairs, Internal Final Report.

Anderson, R.H. 1978. South African beekeeping census 1974/1975. *South African Bee Journal* 50: 7-20.

Begg, K. and Allsopp, M.H. 2001. Practical solutions to the beekeeper and honey badger conflict. *South African Bee Journal* 73(3): 135-138.

Begg, K. and Begg, C. 2002. The conflict between beekeepers and honey badgers in South Africa: A Western Cape perspective. The Open Country N0 4 (Summer 2002): 25-36.

Clark, P. 2012. Tales of an African beekeeper: reflections on bees and beekeeping. Charleston, SC. USA.

COLOSS. 2014. Honey bee research association. Retrieved: 02 October 2014. Retrieved from: http://www.coloss.org/

Conradie, B. and Nortjé, B. 2008. Survey of beekeeping in South Africa. Centre for Social Science Research. Social Surveys Unit. CSSR Working Paper No. 221.

de Lange, W. J., Veldtman, R. and Allsopp, M. H. 2013. Valuation of pollinator forage services provided by Eucalyptus cladocalyx. *Journal of Environmental Management* 125: 12-18.

Du Preez, F.M. 2010. A history of bees and beekeeping in South Africa. Office 444 Govan Mbeki Avenue, Port Elizabeth, South Africa.

Fletcher, D.J.C. and Johannsmeier, M.F. 1978. The status of beekeeping in South Africa. *South African Bee Journal* 50: 5-20.

Johannsmeier, M.F. 2001. Beekeeping in South Africa. Plant Protection Handbook No. 14, Agricultural Research Council, Pretoria.

Melin, A., Rouget, M., Midgley, J.J. and Donadson, J.S. 2014. Pollination ecosystem services in South African agricultural systems. *South African Journal of Science* 110 (11/12): 1-9.

Morse, R.A. and Calderone, N.W. 2000. The value of honey bees as pollinators of U.S. crops in 2000. *Bee Culture* 128: 1-14.

Pirk, C.W.W., Human, H., Crew, R.M. and vanEngelsdorp, D. 2014. A survey of managed honey bee colony losses in the Republic of South Africa – 2009 to 2011. *Journal of Apicultural Research* 53(1): 35-42.

Van der Merwe, W.J. and Eloff, P.J. 1995. Byeboerdery in Wes-Kaapland. *South African Bee Journal* 67: 105-114.

Chapter 3
Status of beekeeping in South Africa: a synopsis from opinion based questions of the forage use survey

3.1 The South African beekeeping industry
Although the South African Beekeeping industry is relatively small both in global terms and local agricultural sector (NAMC Report 2008), it services the important fruit and seed grower industries through pollination contracts. Like in most countries (i.e. Australia, Canada, New Zealand and USA) around the world, beekeepers in South Africa are compelled to register as they own hived colonies. The mandatory registration is specifies in the Government Notice R1674 of 24 December 1998 under the Agricultural Pest Act (Act 36 of 1983). The unwillingness of beekeepers to register under a beekeeping body and adhere to regulations has been a persistent concern. This not only hampers proper registration of hives, easy inspections and monitoring of any diseases, but also prevents effective lobbying for funding and the promotion of beekeeping practices. Beekeepers are reluctant to trust the South African Bee Industry Organisation (SABIO), which is an organised body representing the beekeeping industry in South Africa. The Department of Agriculture, Fisheries and Forestry has since taken over the registration of beekeepers in the beginning of 2014 and now oversee all compliances with regard to beekeeping practices.

SABIO has existed for the past decade, representing beekeeping interests at local, regional, national and international level. It acts as the representative of the South African Beekeeping Industry in all dealings with Government; presides as the consultative spokesperson on all forums affecting the beekeeping industry and agriculture; and strives to set and maintain world-class Apiculture standards in South Africa (SABIO 2014). SABIO's role and responsibilities also include accommodating the interests of bottlers and packers of honey and bee products as well as to the manufacturers of beekeeping equipment. SABIO is also involved in the training of future beekeepers and the implementation of guidelines for food safety and correct packaging of honey. SABIO further liaises with Provincial and/or Regional Beekeeping Associations where possible. There are currently 10 active beekeeping association in South Africa, with Gauteng and Western Cape being the only two provinces with two beekeeping associations per province.

In terms of their communicating function, SABIO ensures that a quarterly bee journal (South African Bee Journal) is published, covering events and research interests in the industry (SABIO 2014). An annual BEECON is organised by provincial association(s) together with SABIO, providing a platform discussing developments in the industry and an opportunity to share ideas. Besides the dissemination of information through the South African Bee Journal, beekeepers have formal email communication groups: the BeesSA and ApicultureSA Google groups. These groups are administered independently and any matter and information relating to beekeeping and agriculture in n general are actively posted-shared and discussed.

It is therefore worrying that the NAMC Report (2008) raised concerns about beekeepers not willing to trust SABIO or any constructive leadership within the industry. Other concerns include beekeepers not interested in sharing apiary site information and honey production figures, as well as making any financial contribution for research purposes. All these hinder the construction of a comprehensive positive industry structure. It would seem that most established beekeepers in the industry (i.e. commercial beekeepers) enjoy the freedom of an unregulated industry to manipulate the situation to their benefit, at the expense of those looking to establish and grow their operations that remain deprived of funding and other opportunities. A united and cooperative beekeeping industry is the only way forward in addressing beekeeper concerns related to forage availability, shortages of colonies for pollination, research needed to support the industry, proper implementation of pollination contracts, regulation of honey imports, irradiation of imported honey, acts of theft and vandalism, reporting of annual colony losses and their causes, hive and apiary sites inspections, and the quarantine as well as control measures for diseases that threaten beekeeping operations.

3.2 Persistent challenges, concerns and threats to beekeeping in South Africa

Major challenges within the beekeeping industry in South Africa have mostly been issues relating to forage, honey production and sales, and diseases (Mike Allsopp pers. comm. 2011). There are just not enough areas that provide adequate forage for maintaining apiaries. In addition, hive theft and vandalism that deters beekeeping in areas of good forage has been labelled as one of the obstacles to honey production (NAMC Report 2008). Together with loss of forage, these have resulted in South Africa being a net importer of honey, thus crippling the local honey market and sales. South Africa has over the years moved from a situation where it was able to produce honey to relying on imports to meet the market demand due to forage shortage (NAMC Report 2008). Beekeepers that can afford to produce high honey volumes struggle to market and sell their honey to local retailers (NAMC Report 2008). Recently, a dialogue about lifting the irradiation requirements for imported honey was initiated after a change in government policy. Beekeepers are concerned that this will be an opportunity for low quality (or even counterfeit) foreign honey to flood the South African market, causing further problems with local honey sales (Miles 2013).

The issue of forage shortage is not unique to South Africa. Pellet (1948) has previously predicted the potential shortage of bee forage not only for South Africa, but other countries as well. Schehle (1996), also outlined possible future threats to the South African beekeeping industry and they included: 1) forage shortage for honey production; 2) high honey imports that threaten the local market; 3) unemployment increasing hive theft and vandalism; 4) the "capensis problem[1]" contributing to major colony declines; 5) increased fuel prices; 6) bee losses due to pesticide use; 7) lack of knowledge and research on bee diseases and the control thereof; and 8) and the mistrust trust among beekeepers making the industry ungovernable. But not much has been done to address these threats since 1996 – something which is of great concern.

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[1] The capensis problem has been documented by several authors (Neumann & Hepburn 2002; Neumann & Moritz 2002; Dietemann *et al*. 2007). This is a parasitic condition that the Cape worker honey bee has on the African/Savanna honey bee. When is outside its native range, the Cape worker honey bee parasitise nests of the African honey bee. They produce pseudo queens which eventually achieve reproductive dominance and cause the demise of colonies. They mimic the queen, perform no duties as workers would (e.g. foraging) and the colonies slowly dwindle in number resulting in massive absconding or death due to starvation.

The availability of funds for bee related research is one other concern for the beekeeping industry. Unlike in the early days of modern beekeeping in South Africa, to date the government has failed to make adequate funding available for bee research (Johannsmeier 2001). Although there is training given to emerging beekeepers, most community beekeeping projects fail shortly after starting, wasting the limited government funding that is made available. Typically long term measures are never put in place to ensure the sustainability of such beekeeping initiatives. Beekeepers are not financially supported in any way by the government.

These challenges, constraints and threats are similar to those outlined by the NAMC Report (2008) and are also the talking points of every beekeeper across the country. But why have the beekeeping industry and the government so far failed to address these perceived threats to ensure the industries' viability? Many beekeepers believe the simple answer to this question is that either the government does not have any interest in governing the beekeeping industry, or that government has a reactive stance to addressing threats when they become a crisis. The reality is that the previously mentioned challenges, concerns and threats will not go away unless tackled and dealt with sufficiently, which can only happen if the South African Beekeeping Industry becomes fully functional and well structured.

Therefore, the aim of this chapter is to investigate the current state of the South African Beekeeping industry by making use of beekeepers opinions and perspectives on the industries' recognition, organisational and support structures, and concerns or challenges faced. Beekeepers' opinions are assessed with the objective of outlining any positive changes relating to previous findings (i.e. NAMC Report 2008). At the same time, new concerns and challenges can be brought to the attention of various institutions, government authorities and concerned parties. Consequently, a number of questions were formulated and included in the forage use questionnaire so that beekeepers could give their opinion on their industry.

3.3 Methods

Question formulation

Section D of the forage use Beekeeper Questionnaire Survey (Appendix A) was used to gather relevant information for this section. A qualitative approach was used in designing the questions. The aim was to derive an understanding of some aspect of beekeepers social relation to their operations/business and their peers, therefore this method allow one to generate worded answers, rather than numbers, as data for analysis (Brikci 2007). Questions asked to beekeepers in the survey were designed to address: 1) how they perceive their business; 2) how they rate their business; 3) how good is their access to research information that can assist their business operations; 4) whether they do get any form of financial aid from the government and 5) what they see as current and potential threats to their business. Questions allowed beekeepers to select answers (yes/no) or to select a rating (poor, satisfactory or good). In most instances a brief motivation for their choice was asked. Only one question required beekeepers to directly specify or list their opinion on the subject.

Data analysis

Responses of beekeepers was categorised based on the choice answer and/or rating given, outlining the total of each category, with those beekeepers that opted not to select any of the choices given categorised as “no response”. For example, if there was only a yes and no option, three category answers are generated as yes, no and no response. A similar approach is adopted for the rating options and this allowed full accountability of complete responses. In sections where motivation was required, a coding system was developed as some of the answers were too long to record. Coding of phrases for analysis in quantitative research allows one to use certain key words representing segments of texts or phrases for easier data analysis (Denzin & Lincoln 2000). In this regard, this method made it easier to derive finer and shortened categories from the data gathered form the initial response phrases. This criterion is directly applicable to questions 2, 3, 4 and 6. In some instances, beekeepers gave more than one reason in motivating for their choice category. The total number of respondents per coded choice category was then treated independently.

Limitations to the questionnaire method: truthfulness and results biases

Studies with an aspect of understanding particular elements of a group or society are often referred to as basic research (Bless *et al*. 2007). In this case, I undertook this section of the study gain insight of the situation (status) and concerns of the beekeeping industry. Questions were semi-structured to gain in depth knowledge about the proposed topic. Because the questionnaires were postage based (mail and postal), I cannot account for any false submission (e.g. the intrusion of non-respondent) in the answering of the questionnaire (Babbie & Mouton 2001). For this section in particular, I accept the general findings as provided by the respondents. In addition, conducting a one on one (face-to-face) interview would have not fully illuminated false submission as the interviewer might trigger the interviewer effect (Bryman 2012). The major drawback with the face-to-face interview is the presence interviewer bias. In the context of research, characteristics of the interviewee may prompt the interviewer to exhibit various cues to the interviewee, resulting in skewed or biased responses. Either way some level of bias or full truthfulness relating to questionnaires is difficult to account for unless there is applicability, consistency, neutrality, truth-value and validity checks or tests (Zwaan 2013). Of which, neither was carried out for this study.

I further consider the possibility of respondents not answering questions correctly or not entirely honest with their answers. However, this is difficult to verify as it results from reason that differ from one respondent to another (Bryman 2012). For example, some respondent might have not understood the question correctly or that they were fatigued when answering some of the questions. As a result, some form of bias is possible in responses given may be incorrect. It is has been shown that some respondents disclose more information under anonymous conditions compared to others (Ong & Weiss 2000). Hence, the study assured participants in both surveys some anonymity (see Appendix E) to to improve the chances of full disclosure. Therefore, it is assumed that the responses gathered are in favour of the latter.

3.4 Results

Question 1: How would you like your industry/profession to be recognised or considered?

For this question beekeepers were given two options, Beekeepers or Honey bee Service Providers. A total of 155 respondents indicated that they would prefer being referred to as beekeepers, while 34 would rather be recognized as Honey bee Service Providers and 28 did not respond (Figure 3.1). A category which was not initially accounted for, Hobbyist had a single respondent.

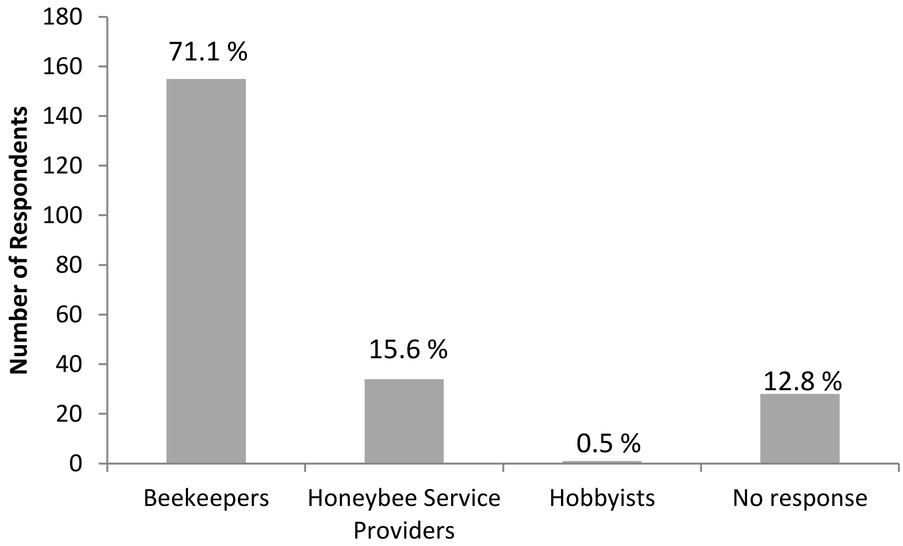

Figure 3.1: Beekeeper responses on their industry/profession recognition preference

Question 2: How would you rate the quality of beekeepers in South Africa?

The majority of respondents indicated that the quality of beekeepers across the country was satisfactory (43 %). Beekeepers thought that 25 % of their compatriots were of poor beekeeping standard, as opposed to only about 19 % whom rated the quality of beekeepers as good (Figure 3.2). Only 14 % of the respondents chose not to give a rating for this question.

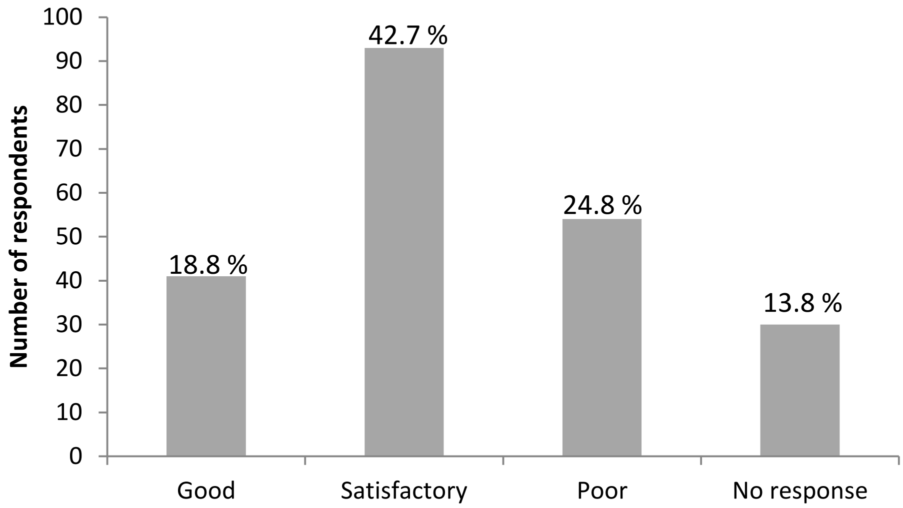

Figure 3.2: Beekeeper response rating on the quality of South African beekeepers

Beekeepers were also asked to briefly motivate for the selected rating above, with a total of 25 reasons given (Table 3.1). The two most common reasons provided were that of beekeepers being honest, hardworking and generally having good relations. The least prevalent reason was that of bee poisoning, which was mentioned by a single respondent. Generally, the reasoning was a mixture of reasons directly related to indirectly related matters that can be used to class or quantify beekeeper quality with respect to beekeeping (Table 3.1).

Table 3.1: Factors listed by beekeepers as motivating their rating on the quality of beekeepers in South Africa. Number of respondents is out of a possible 218 beekeepers that completed the forage questionnaire.

Reasons	Number of respondents
Honest, hardworking and good relations	32
Generally good and helpful beekeepers	27
Selfishness	24
No funding	13
Unregistered beekeepers	12
Dysfunctional organisation	11
No good research	11
Little knowledge and experience	10
Low hygiene & poor hive conditions	10
Courses run and dissemination of information	9
Secrecy on knowledge, ideas & forage sites	9
Mistrust among beekeepers	7
Political infighting	7
No Law enforcement	7
Production of good honey	6
Experienced and knowledgeable	6
Poor equipment	6
Poor to no training	6
Use of out dated methods	5
No market for products	5
Aging beekeepers	4
Cheap and low quality honey imports	3
Vandalism and theft	3
Corruption	2
Poisoning of bees	1

Question 3: How would you rate the state of beekeeper organisations in South Africa?

The satisfactory and poor rating options received equal responses of 37 % each for this question (Figure 3.3). Only 10 % of respondents indicated that the state of beekeeper originations was good, with 17 % of the beekeepers not responding.

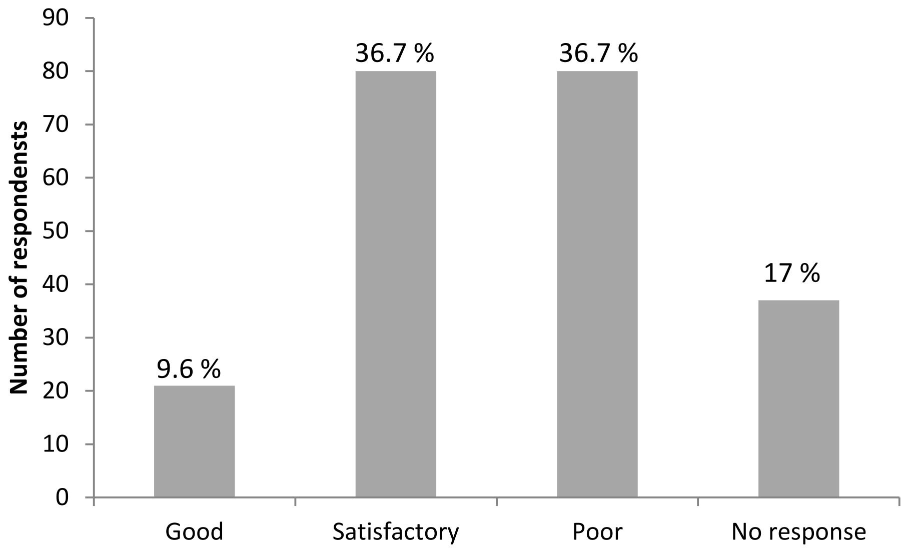

Figure 3.3: Beekeepers rating of the state of beekeeper organisations in South African

A total of 14 reasons were given in support for the ratings in Figure 3.3. Unstructured and incompetent beekeeper associations were the most stated reason with 30 respondents. Lack of unity and lots of secrecy were the other common reason given by beekeepers (Table 3.2). Corruption within associations was the least cited reason, with a single respondent. It is worth noting that responses given here addressed problems, whereas strengths were not generally noted in the reasons expect for “SABIO & provincial associations doing well given limited funds” and “Supportive, Responsible & sharing information”.

Table 3.2: Reasons given for the rating of beekeeper associations in South Africa. Number of respondents is out of a possible 218 beekeepers that completed the forage questionnaire.

Reasons	Number of respondents
Unstructured provincial beekeeper associations and incompetence	30
No unity and lots of secrecy	29
No research, infrastructure and funds	26
Political infighting	24
SABIO & provincial associations doing well given limited funds	24
Supportive, Responsible & sharing information	13
Varies according to associations	12
Unregistered beekeepers	10
No assistance for small beekeepers	8
No law and regulations enforcement	6
No communication	6
SABIO's mismanagement & incompetence	5
No market for products	2
Corruption	1

Question 4: Do you think the South African Government is offering adequate support to the beekeeping industry?

A total of 150 (69 %) respondents indicated that the government does not offer the beekeeping industry any kind of support. In contrast, 24 (11 %) respondents felt that there is some of form of support given to the industry. Forty four beekeepers (20 %) opted not to respond. Respondents then gave suggestions on how the government should get involved in supporting the industry. Funds for research, infrastructure and training programmes were highlighted by overwhelming majority of the respondents (Table 3.3). Other suggestions that were favoured by many respondents related to matters around regulations and law enforcement of certain beekeeping activities and aspects (Table 3.3).

Table 3.3: Suggestions provided by beekeepers on how the government can get involved in supporting the beekeeping industry. Number of respondents is out of a possible 218 beekeepers that completed the forage questionnaire.

Suggestions	Number of respondents
Fund research, infrastructure and training programmes	108
Regulation of honey imports	35
Enforce inspections, regulations and registration	31
Law enforcement on theft, vandalism and bee poisoning	28
Disease control	27
Forage provision and research	13
Marketing of products	7
Protecting and conserving forage	6
Never will and must not get involved	6
Address the “capensis problem”	2

Question 5: Do you find it easy to access information (i.e. research papers, technical developments etc.) that you feel are of importance for your industry/organisation to be successful?

Majority (54 %) of the respondents indicated that they do find it easy accessing relevant beekeeping information compared to the 30 % who found it difficult in accessing such information. There were also respondents who opted not to give any formal response (Figure 3.4).

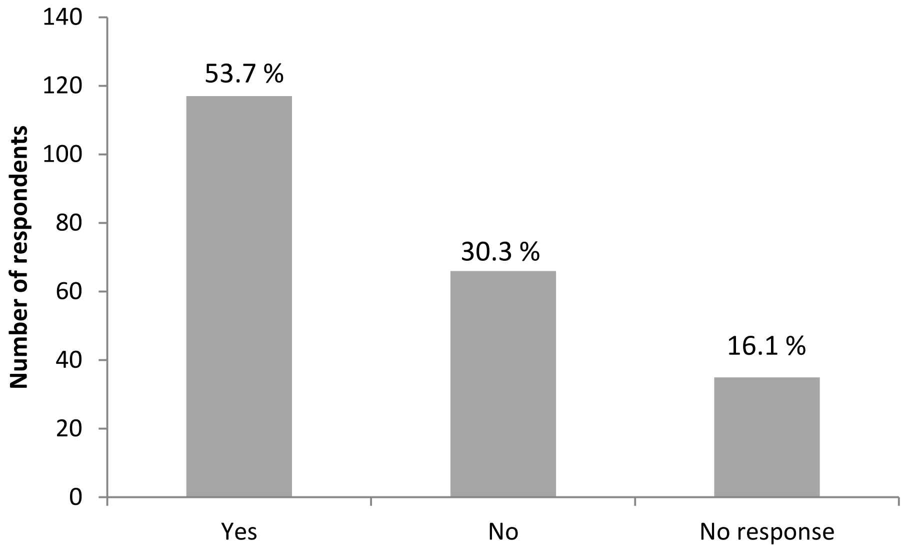

Figure 3.4: Access to relevant beekeeping information

Question 6: In your opinion, what are the most important threats facing your industry/organisations?

A total of 24 potential threats to the beekeeping industry were identified. Vandalism, loss of forage and honey imports were the most cited threats, with 116, 114 and 97 respondents respectively. In contrast, poor hive quality and hygiene were the least recognised threats (Table 3.4).

Table 3.4: Potential threats to the beekeeping industry identified by beekeepers. Number of respondents is out of a possible 218 beekeepers that completed the forage questionnaire.

Potential threats identified	Number of respondents
Vandalism	116
Loss of forage, Removal of gums & non flowering gums	114
Honey imports	97
Theft	45
Diseases	43
Pesticides	23
No Financial support from the government	16
No beekeeper unity	14
Political infighting	13
Lack of law enforcement	13
No proper research	11
No product market	10
Lack of education, training and Information	9
Honey badger	9
Dysfunctional beekeeper organisation	8
Wild fires	7
Climate change	6
Fuel price	5
Ignorance	4
Economic meltdown	3
"Capensis problem"	3
Poor hive quality and hygiene	2

3.5 Discussion

Prior to this study, Schehle (1996) highlighted some of the likely challenges the South African beekeeping industry face. Other studies and reports also briefly touch on the beekeeping trends and challenges within the industry (see Allsopp & Cherry 2004; Conradie & Nortjé 2008; NAMC Report 2008). Findings and concerns highlighted by all these authors are also prevalent in my findings. Loss of forage, hive theft and vandalism, lack of financial backing from the government, influx of honey imports, unstructured and non-cooperative beekeeper associations, challenging economic climate and lack of co-ordinated bee research, are some of the common themes raised by beekeepers in these previous studies and the current study. The persistence of these concerns is indicative of the failure by the institutions or bodies concerned to address these matters in South Africa.

It is important that these concerns are addressed if the industry is to grow and advance to its potential as outlined in the NAMC Report (2008). This can be done by first recognising the value of the beekeeping industry regarding its importance to commercial crop pollination (therefore the country's economy), honey production and sustainable livelihoods. But all needs to start with constructive dialogues between parties, something beekeepers have always felt the concerned parties fail to honour. Beekeeping needs to be prioritised along with other agricultural related practices, and this will enable the industry to get the recognition it deserves going forward.

For clarity and unpacking the responses for each of the question in section 2, the respective responses are fully discussed in the section below.

3.5.1 Industry/profession recognition

This question was posed with the aim of understanding how beekeepers wish to be recognised given their beekeeping operations and practices. It was strongly evident that South African beekeepers still prefer to be recognized as beekeepers as opposed to Honey bee Service Providers. This indicates that in their profession the emphasis is still on keeping and managing honey bees than the service they provide to clients.

3.5.2 The perceived quality of beekeepers in South Africa

The quality of beekeeping can be rated using various variables although this is bound to different among beekeepers since they have different beekeeping skills and methods. Also it must be taken into account that a beekeeper assessment of this nature has never been documented in South Africa. Therefore, a comparison of the past and present if not possible. Nonetheless, the management and hygiene levels of beekeeping practices across the country are highly commended (Allsopp 2006; Human *et al*. 2011), and thus supports beekeepers perception that they are preforming satisfactorily. In contrast, some beekeepers did highlight low hygiene and poor hive conditions, which have the potential to promote the harbouring and transmission of diseases, pests and pathogens (vanEngelsdorp & Meixner 2010; Somerville 2012). This does indicate that there are still beekeepers that should improve their operations. Some of the other aspects requiring improvement stated by respondents were at a glance seemingly inappropriate for the subject in question, but these do have indirect impact on beekeeping and the quality of service rendered or products produced.

3.5.3 The state of beekeeper organisations in South Africa

The question posed to determine the beekeeper organisation had the possibility to be influenced by beekeepers affiliation or the absence thereof to such an organisation. Also, this would differ among individuals and provinces. The decision to rate the organisations as satisfactory or poor could have also been based on their experiences. Provincial and/or Regional Beekeeper Associations have over the past years struggled to get their structures in order. It has in most instances been those in the Gauteng, Western Cape and KwaZulu-Natal that are well organised and best run (Mike Allsopp pers. comm. 2012). Issues around leaderships, funds, infighting and incompetence are some of the matters perceived to hinder proper functioning of beekeeper associations around the country. It is for such reasons that break away associations (i.e. SAAFED) are common, although their motives and sustainability remain questionable.

It is also important to note that some of the concerns highlighted here, have previously been documented in the NAMC Report (2008). This highlights the persistence and re-occurrence of these concerns and the failure to address them adequately. At the same time, SABIO and various provincial associations are applauded for their efforts in representing beekeepers well despite limited resources.

3.5.4 Government support to the beekeeping industry

Here, of the majority of respondents (69%) indicated that the government does not provide any form of funding to the beekeeping industry. This was concurrent with the NAMC Report (2008) findings on the states' lack of involvement, particularly in financial aspects, in beekeeping related matters. However, there have been several beekeeping projects in the past decade funded by the government in collaboration with SABIO, but most have since collapsed (Mike Allsopp pers. comm. 2012). Reasons behind the collapse of these projects centre on the misuse of funds, leadership crisis, lack of forage as well as theft and vandalism. To some extent, the beekeepers' reiterations about the lack of support (mostly funding) by the government might be seen as biased given the interventions with beekeeping development projects. In addition, this could be because of mistrust or dislike towards the government. However, the views and opinions of beekeepers needs to be respect – particularly when same views remain relevant almost eight (8) after the conclusion of the NAMC Report.

When beekeepers were asked to list ways in which the government can or should get involved in supporting the industry, suggestions made were similar to those observed in the NAMC Report (2008). Topping the list was funding for research, followed by infrastructure development and training programmes. It is important to note that the issue around funding was also highlighted in the past three questions addressed above – an indication of the desperate need of finances to better the running of the industry. Regulations of honey import was also mentioned, an important matter currently as discussions around lifting the enforcement of irradiation measures on imported honey are ongoing (SABJ 2013). Beekeepers have always perceived the import of honey for the South African market as a threat to their domestic business (Masehela & Veldtman 2015). At the same time, beekeepers are unable to meet the demands of the honey market locally (NAMC Report 2008). In fact, the demand for honey in South Africa ranges between 2700 and 3000 tonnes per annum, while local production is estimated to be between 1700 and 2000 per annum (NAMC Report 2008), a shortfall of roughly 1000 tonnes annually.

There is a general perception that beekeepers are not keen on the idea of strict regulations and enforcement for beekeeper registrations and inspections, but findings here suggest otherwise. A total of 31 respondents indicated that government needs to have a strong hold on inspection and registrations. Taking into account the current Department of Agriculture Fisheries and Forestry beekeeper registrations (see Chapter 2), beekeepers do comply with registrations. The registrations captured higher beekeeper numbers (1069) compared to that of the South African Bee Industry Organisation, which stood at 212 registrations as of January 2016 (SABIO Communique 2016). Vandalism, theft, bee poisoning, loss of forage, disease control and addressing the "capensis problem" were also on the forefront of matters that beekeepers would like to see the government address through proper regulation.

Another listed suggestion worth highlighting, is six respondents that are of the opinion that the government should not get involved in beekeeping related matters since they never bothered in from the start. Although this might come across a bit harsh, it also highlights frustrations and lack of confidence that some of the beekeepers have with the government where beekeeping is concerned. However, Mr Mooketsa Ramasodi (Deputy Director at the Department of Agriculture Forestry and Fisheries) assured beekeepers during his presentation at the BEECON 2013, that the government is willing to work with beekeepers on their concerns towards insuring that beekeeping matters are adhered to especially where structuring, legislation and funding is concerned. To date, there are no signs of these words becoming a reality.

3.5.5 Access to information of relevance and importance for the industry

A general lack of access to bee related research in South Africa was identified. This may be due to the information generated by research not being well distributed or that it is limited to certain aspects of beekeeping in South Africa. In most instances, beekeepers rely on the South African Bee Journal and other agricultural related magazines to obtain the relevant information to their industry. The BeesSA and ApicultureSA Google groups also play a strong role in the sharing of information amongst beekeepers.

3.5.6 Threats facing the beekeeping industry

Responses given for this question were similar to the challenges highlighted extensively in the NAMC Report of (2008). Issues around the industry structures and operations, enforcement of legislation and regulations, marketing of honey and other bee related products, training, beekeeper developments, lack of forage, inadequate research and regulations of honey imports were again reiterated. Therefore, elaborating further on these threats will be a repetition of the analysis and recommendation outlined in the NAMC Report (2008). However, the importance of these issues must not go unresolved as they have the potential to escalate over time.

There were a few new issues raised, such as the escalating fuel prices and climate change. Fuel prices affects day to day running of beekeeping practices as beekeepers spend most their time searching for good apiary sites, visiting their hives and maintaining good security measures. During the pollination season or migratory periods in search for better nectar flows, beekeepers cover long distances. All this is impacted heavy by the rise of fuel costs. There are yet studies to demonstrate how climate change could potentially impact honey bee populations. However, indirect environmental impacts due to climate (i.e. drought) have the potential to directly influence beekeeping practices (Le Conte & Navajas 2008).

3.6 Conclusion

In this chapter, the opinion based questions used in the beekeeper questionnaire successfully outlined the current state of operations and relations within the beekeeping industry. Majority of the concerns are not new and appear consistent among respondents. Despite these concerns being listed for the last two decades, nothing seems to have been done in addressing them. There is however a few positive points that can be drawn which relate to the quality of beekeepers and to some extent the operations of various beekeeping organisations. That said, it is clear that issues relating to forage shortage, funding, research, honey imports, vandalism and theft and honey marketing are persistent problems and needs effective intervention. Beekeepers were divided regarding the cohesion among themselves and it was not outright clear whether there are certainly divisions or if there is unity and trust within the industry and organisation structures. At the same time, beekeepers seem keen to have better regulations in place and work with the government in insuring that these are enforced towards a functional-viable beekeeping industry.

Perhaps a united and cooperative beekeeping industry is the only way forward in addressing beekeeper concerns to forage availability, shortages of colonies for pollination, research needed to support the industry, proper implementation of pollination contracts (address undercutting by other beekeepers), regulations of honey imports, irradiation of imported honey, access to honey markets (locally and abroad) acts of theft and vandalism, reporting of annual colony losses and their causes, hive and apiary sites inspections, and the quarantines as well as control measures for diseases that threaten beekeeping operations.

Going forward, a bee directorate needs to be established within Department of Agriculture Fisheries and Forestry, to directly address matters and challenges of the industry. These should include matters raised in the NAMC Report (2008), in this study, with priority given to the reestablishment of a well-funded, fully-operational national bee unit.

3.7 References

Allsopp, M.H. and Cherry, M. 2004. An assessment of the impact on the Bee and Agricultural industries in the Western Cape of the clearing of certain Eucalyptus species using questionnaire survey data. Pretoria (South Africa): National Government of the Republic of South Africa, Department of Water Affairs, Internal Final Report.

Allsopp, M.H. 2006. Analysis of Varroa destructor infestation of Southern African honey bee populations. MSc Dissertation, University of Pretoria, Pretoria.

Babbie, E.R. and Mouton, J. 2001. The Practice of Social Research. Oxford University Press Inc., New York.

Bless, C., Higson-Smith, C. and Kagee, A. 2007. Fundamentals of Social Research Methods. An African Perspective. Cape Town: Juta.

Brikci, N. 2007. A guide to using qualitative research methodology. Retrieved: 08 November 2013. Retrieved from: http://fieldresearch.msf.org/msf/bitstream/10144/84230/1/Qualitative%20research%20methodology.pdf

Bryman, R. 2012. Social Research Methods, 4th Edition. Oxford University Press Inc, New York.

Conradie, B. and Nortjé, B. 2008. Survey of beekeeping in South Africa. Centre for Social Science Research. Social Surveys Unit. CSSR Working Paper No. 221.

de Lange, W. J., Veldtman, R. and Allsopp, M. H. 2013. Valuation of pollinator forage services provided by Eucalyptus cladocalyx. *Journal of Environmental Management* 125: 12-18.

Denzin, N.K. and Lincoln, Y.S. 2000. (Eds). Handbook of qualitative research, 2nd Edition. Sage Publications, Inc. London, United Kingdom.

Dietemann, V., Neumann, P., Härtel, S., Pirk, C.W.W. and Crew, R.M. 2007. Pheromonal dominance and the selection of a socially parasitic honey bee worker lineage (*Apis mellifera capensis* Esch.). *Journal of Evolutionary Biology* 20: 997-1007.

Dietemann, V., Pirk, C.W.W. Crewe, R. 2009. Is there a need for conservation of honey bees in Africa? *Apidologie* 40: 285-295.

Human, H., Pirk, C.W.W. Crewe, R.M. and Dietemann, V. 2011. The honey bee disease American foulbrood – An African perspective. *African Entomology* 19: 551-557.

Johannsmeier, M.F. 2001. Beekeeping in South Africa. Plant Protection Handbook No. 14, Agricultural Research Council, Pretoria.

Le Conte, Y. and Navajas, M. 2008. Climate change: impact on honey bee populations and diseases. *Revue scientifique et technique* (International Office of Epizootics) 27(2): 485-97, 499-510.

Masehela, T.S. & Veldtman, R. 2015. Relating bee forage to honey production – honey on the market is not a good indicator of important honey crops. South African Bee Journal 87 (3): 524-527.

Miles, M. 2013. Eastern Highveld Beekeeper's Association Newsletter for September 2013. *South African Bee Journal* 85(3): 130-132.

NAMC Report. 2008. 3rd Draft Report. A section 7 committee investigation. The South African Beekeeping Industry. Pretoria, South Africa.

Neumann, P. and Hepburn, H.R. 2002. Behavioural basis for social parasitism of Cape honey bees (*Apis mellifera capensis*). *Apidologie* 33: 165-192.

Neumann, P. and Moritz, R.F.A. 2002. The Cape honey bee phenomenon: the sympatric evolution of a social parasite in real time? *Behavioral Ecology and Sociobiology* 52: 271-281.

Ong, A.D. and Weiss, D.J. 2000. The Impact of Anonymity on Responses to Sensitive Questions. *Journal of Applied Social Psychology* 30 (8): 1691-1708.

Pellett, F.C. 1948. The bee pasture problem. *South African Bee Journal* 22: 10-12.

SABIO. 2014. About SABIO. Retrieved: 07 September 2014.
Retrieved from: http://sabio.org.za/

SABIO Communique. 2016. Communique #01/2016. 1-9.

SABJ. 2013. Newsletter for September 2013. *South African Bee Journal* 85 (3): 130-132.

Schehle, A. 1996. Die huidige stand van die Suid-Afrikaanse bye-industrie. (The present status of the South African bee industry). *South African Bee Journal* 68(5): 137-140.

vanEngelsdorp, D. and Meixner, M.D. 2010. A historical review of managed honey bee populations in Europe and the United States and the factors that may affect them. *Journal of Invertebrate Pathology* 103: 580-595.

Zwaan, T.C.M. 2013. Exploring factors that contribute to sport participation among boys in the middle childhood phase. MSc Dissertation, University of South Africa, South Africa.

Chapter 4
Forage use for honey production in the South African beekeeping industry

4.1 Honey relevance to beekeeping

Honey is a naturally sweet food produced by honey bees using nectar collected from various flowering plants (Crane 1980). Honey bees use honey as their primary food source produced by transforming nectar into honey through a process of process of regurgitation and evaporation. It is stored in honeycombs, covered by wax, then left to mature and ripen (White & Landis 1980). The association of humans and honey usage dates back to the dawn of civilization (Beck & Smedley 1947; Johannsmeier 2001). The use of honey is preferred for different food sources, but also plays a critical role religiously (Beck & Smedley 1947) and medicinally (Herold 1970; Crane 1975). Over the years, beekeepers have learned to keep and manage honey bee colonies to harvest, packaged and sell honey to creating employment within the beekeeping industry itself and earning income to better their livelihoods (Johannsmeier 2001; FAO 2009).

To make honey, forage by means of nectar must be adequately available and accessible for honey bees. Pollen is equally important for the growth and development of the colony (Brodschneider & Crailsheim 2010). Natural and semi-natural habitats are suitable areas for honey bees to forage (Gathmann & Tscharntke 2002; Klein *et al*. 2002; Potts *et al*. 2005; Decourtye *et al*. 2010; Samnegard *et al*. 2011). These areas are beneficial due to the variety of flowering plants available and this is importance since honey bees (other insects included) require a diverse community of flowering plants that flower for longer periods, irrespective of whether these species are native or exotic (Levy 2011). Under normal circumstances, honey bees forage on palatable and most nutritious flowering plants in order to meet their nutritional needs, while at times maintaining their preferences of pollen and nectar sources of plants when various plants are flowering simultaneously in the environment (Bilisik *et al*. 2008). During dry to forage scarce periods, honey bees will however collect anything sweet (Johannsmeier 2001).

A beekeeper can only harvest honey from his managed colony when the foragers of a colony have collected more than enough nectar to maintain the colony resulting in a surplus of stored honey. Because different forage sources flower at specific and different times of the year, it is difficult for beekeepers to make use of a single forage source throughout the year for nectar flows (Johannsmeier 2001). Consequently, most beekeepers opt for transporting their colonies across various landscapes in order to find suitable foraging sites (or apiaries) with access to substantial honey flows (Morse & Calderone 2000; Johannsmeier 2001; vanEngelsdorp & Meixner 2010). Such managed migrations are simultaneously important for colony maintenance (defined as the colony survives and remains healthy) and honey production, and are therefore dictated by forage accessibility and availability.

4.1.1 The honey trade

A 2005 report by the Trade and Industry Policy Strategies (TIPS) outlined the world honey market to be valued at $ 738 million. China, Turkey and Argentina are the top honey producers respectively with China having produced 306 000 tons of honey in 2006 (NAMC Report 2008).The world honey trade is often described as less volatile market mostly dictated by the top exporters (CBI Market Survey 2009), with the majority of the honey being produced in developing countries (TIPS 2005). In Africa, Ethiopia and Tanzania are the top honey producers while the Southern African Development Community (SADC) region countries are net importers except Zambia (Situation Analysis of Beekeeping Industry, *publication date unknown*). South Africa produces approximately 1700 tons of honey annually, while importing >2700 tons with almost 55% of the imported honey coming from China (NAMC Report 2008). Honey exports to neighbouring countries are less than 160 tons annually (NAMC Report 2008).

Reasons for South Africa not producing enough honey for local consumption vary widely. For instance, South Africa is a semi-arid country and there is not a lot of plant biomass to produce forage relative to the tropics (Brazil and Zambia) and moist temperate areas (Argentina and China). Also, the removal of Eucalyptus trees (which can contribute significant forage in even semi-arid areas) results in the loss of good forage with abundant honey yields (Allsopp & Cherry 2004). The NAMC Report (2008) outlines that in 2006, imports from China to South Africa were priced at R7.84 per kg whereas it costs South African beekeepers between R11.00 to R15.00 to produce a 1kg of honey that sells above R25.00 per/kg. As of April 2014, a kilogram of honey sells for anything between R30.00-R35.00 per/kg (Anonymous 2014). The current review of lifting irradiation measures for SADC imported honey puts more pressure of the locally produced honey and stands to influx the market with low-priced non South African honey, which the beekeepers will find tough to compete with commercially. This could also see the 22% import tariff levy being removed, a though most beekeepers find disturbing as it leaves many questions unanswered (Allsopp, pers. comm. 2014).

South African does not produce nearly enough honey for the domestic market, although prices are fairly good and allows for a substantial profit margin (NAMC Report 2008). Similarly, the honey market is a bit different from most common agricultural markets due to the specificity of the different types of honey available and preferred by consumers. For example, the origin and colour of the honey might be the bench mark for the pricing, while the quality and origin also influence the pricing (TIPS 2005). Generally, light coloured honey receives a higher price due to being easily liked by the public. Honey of certain vegetation or iconic floral regions (i.e. natural forests) tend to also be pricey due to their perceived rich taste novelty (DAFF 2005). Besides colour, origin and taste, honey preferences can also be based on medicinal properties. For example, the globally renowned Manuka honey produced in New Zealand and Australia from the nectar of the Manuka tree (*Leptospermum scopariumis*) has over the years remained competitive in the market based on its medicinal properties preferences (Weston *et al*. 1999).

4.1.2 Bee Forage (flora) determines honey production

Honey bees require substantially good forage for their survival and optimal colony productivity (Brodschneider & Crailsheim 2010). At the same time, the type of forage available determines the kind of honey produced. Honey may vary differently in colour and taste, depending on the forage source of the nectar (Crane 1975). Therefore, beekeepers also distinguish and value forage differently depending on the type of contribution they associate it with for their honey production. Underpinning the forage availability is the climatic conditions (Attridge 1923; Johannsmeier 2001; Levy 2011) and the landscape (habitat) practices and activities in respective areas (Biesmeijer *et al*. 2006; Klein *et al*. 2007). As such, regions will produce a certain type of honey related to that particular forage's availability and its association with suitable climatic conditions.

Some of the iconic honey from certain areas includes that of Acacias and Buckwheat from China, Orange blossom from Mexico and the United States of America (USA), and Clover from Canada, Argentina and Australia (PIPS 2005). In countries such as India (Thomas et al. 2002); Cameroon, Mozambique, the Rodriguez Islands and New Guinea (D'Albore & Piatti 2004); Israel (Keasar & Shmida 2009), Ethiopia (ESAP 2006) and South Africa, Eucalyptus trees constitute to the majority of the honey produced. For South Africa in particular, more than 50 % of the honey produced is from Eucalyptus (Johannsmeier 2001; Allsopp & Cherry 2004). Citrus, Fynbos and Sunflower honey are also common but their contribution to total honey production is minimal compared to Eucalyptus (Johannsmeier 2001 & 2005).

According to Johannsmeier (2001) and more recently Hutton-Squire (2014) honey production in South Africa is not possible without Eucalyptus. Allsopp & Cherry (2004), also reiterate that Eucalyptus species are vital to the Western Cape Province (biggest beekeeping province), not only for honey production but also for colony maintenance. They stress that in any event that will result in the loss of most or even all Eucalyptus species the beekeeping industry would collapse in the province. Considering the importance of Eucalyptus for honey crop in South Africa, beekeepers do not own most of the land on which these trees occur or any land where their bees are kept. The removal of certain Eucalyptus trees in various parts of the country (particularly the Western Cape) has further reduced the available honey crop (Allsopp & Cherry 2004).

Preferred honey crops in other provinces of South Africa are poorly known or even unknown due to the lack of documentation. Beekeepers possibly have their own ledgers or journals of such, but no publications are on record or freely available. There is therefore a need to document the use of forage by beekeepers and assess the overall importance of various honey crop forage species, per province. In this chapter, I document the forage types used for honey production in all nine South African provinces. I also determine what their percentage contribution is to honey production. Here, I hypothesize that all forage types are used equally for honey production. Lastly, I record the number of different areas used for forage contributing to honey production. In this chapter: 1) forage category refers to exotic and indigenous; 2) forage type refers to Eucalyptus, agricultural crops, weeds, suburban plantings, Indigenous genera and vegetation units; and 3) forage sources are individual species as listed by scientific or common name.

Specifically, I address the following questions:

1. Does the number of species per forage type and category used for honey crop vary across provinces?
2. What percentage of the colonies kept per province does each forage type and category support for honey production and what is the frequency variability among forage types?
3. Which honey crop forage sources (species and vegetation units) support more than 5% of a province's managed honey bee colonies, and thus of general importance?
4. Is there variation among provinces in the relative number of colonies that are kept per locality[2]? What are the localities of respective forage sources provincially (nearest town), and how does this relate to number of respondents and colonies kept per locality?

4.2 Methods

<u>Data collection</u>

The beekeeper questionnaire survey outlined in Chapter 2 (Appendix A) was used for data collection for this chapter. Only Section A (number of colonies) and E (forage use patterns) of the questionnaire was considered for the purpose of this chapter. In section A, beekeepers had to indicate the total number of colonies they actively manage. For the forage type and use data table, Section E, beekeepers were provided with an outlined list of various plants known to be used by honey bees in South Africa (Johannsmeier 2001 & 2005;

[2] Locality refers to an area (not exact location) or apiary site – stationary or rotational that beekeepers use and/or place their hives to access forage at a particular time of the year/season. Beekeepers do not generally give/name their exact locality in order to protect their forage sites or avoid competition. Locality and apiary site are often used interchangeably in beekeeping context. This definition applies to other chapters where the term is used or applicable.

Allsopp & Cherry 2005; Mouton 2011) to choose from when indicating which forage their bees use. The table provided additional space for beekeepers to add other plants that their managed bees forage on, if not on the provided list. In the Honey crop, beekeepers had to indicate what average percentage of their colonies best benefit from which forage type/source. The honey crop category summed up to 100% for each beekeeper. For each forage type/source, distribution area(s) by means of a closest town had to be stated and the flowering period in months.

It is important to note that the questionnaire did not ask beekeepers to state whether they use fixed or rotational localities. Therefore, the period or frequency in using each locality at a given time during the year or season could not be established. Also, beekeepers would not disclose this information if asked – this relates explanation given in the footnote of the pervious page. It is generally accepted that beekeepers use localities depending on the suitable forage available and accessible within a locality at a given time.

Data analysis

Section E data: The captured average percentage colony (%) dependence on each forage source indicated the importance of that particular forage source to honey production. For estimates of colony numbers, the average percentage colonies given are reverted to relative colony numbers. For example, if a beekeeper indicates that he has an ***x*** number of colonies (in section A); then in section E he indicates that on average, y% of his ***x*** colonies use ***forage b*** for honey crop, then the following equation (Equation 1) was applied:

$$\boldsymbol{Relative\ colonies\ for\ honey\ crop} = (\boldsymbol{Average\ colonies}\ \div \mathbf{100}) \times \boldsymbol{Total\ colonies\ owned}$$

Forage sources of common use amongst beekeepers within the same province were counted only once with colonies associated with that particular forage source added together for their contribution as honey crop for that province. Chi-square was used to establish whether the frequency of use between the various forage categories were the same or has any level of significance. The significance of differences were determined by Likelihood Ratio X^2 analyses for the six forage types for each province. Bloom periods in months were listed as per the best knowledge of the beekeeper and validated by using

Johannsmeier (2001 & 2005) for those species that are on record. Those not previously on record are treated as new entries with the stated bloom period adopted. Bloom periods are not presented and discussed in the body of this chapter but listed in Appendix C as the given times (in months) could not be verified for majority of the listed species using existing records (e.g. Johannsmeier 2001 & 2005). For forage localities, all listed areas are taken into consideration meaning that if there is more than one locality listed per source then the relative number of colonies for that particular forage is divided by the total number of listed localities. Here it is assumed that those particular colonies use the listed areas equally for the duration of their placement in that area. For this purpose I only report on the number of respondents, total number of localities and average percentage colonies per localities for each province.

Limitations to the questionnaire method: truthfulness and results biases

Beekeepers create their own bee forage calendars (Clark 2012). They keep records of the type of forage their bees use at respective sites as well as their flowering periods. This is important as it links with the prioritisation of their respective beekeeping practices. Beekeepers need to know when to best move their hives to take advantage of a particular forage source depending on whether they wish to focus on honey production or strengthening their colonies. This varies from season to season. Therefore, the forage information provided by beekeepers in this chapter relates solely to honey crop plants. Beekeepers best know which plants to use and when. As a result, this information is trusted to be truthful and accurate. It is worth noting that beekeepers could be biased on stating which forage plants best matter to them for honey production, but is likely because they prefer those particular plants to others. There is no way of accounting for these biases. The respective sections here simply acknowledge the use and importance of each forage source as stated by the beekeepers. This explanation is also applicable to Chapters 5 and 6 where the use and importance of different forage sources are discussed.

4.3 Results

4.3.1 Percentage contribution of forage categories and forage types

Exotic forage was preferred in seven of the nine provinces and supported over 65% of the colonies (Figure 4.1). The Eastern and Northern Cape Provinces were the only two provinces whereby more than 50% of colonies used Indigenous forage for honey crop (Figure 4.1). Within the exotic forage category, Eucalyptus and agricultural crops were the most used forage types supporting over 25% colonies in eight and five provinces respectively (Figure 4.2). Interestingly, Eucalyptus was the only forage source to support over 10% colonies in all provinces. Suburban plantings were only used extensively in the Free State, compared to other provinces. Indigenous forage use was marginal except for the Eastern Cape, Northern Cape and North West whereby Indigenous genera over 25% colonies each (Figure 4.2). The Western Cape was the province with the greatest use of vegetation units (<15%), but overall the forage type was of minor importance.

The frequency of use and the relationship thereof was also variable for the different forage types across provinces (Table 4.1). In the Eastern Cape, Agricultural crops and vegetation units use was not significant compared to other forage types (Table 4.1). For the Free State and Gauteng, Eucalyptus was very significant ($p<0.001$) compared to other forage types. In KZN, the overall frequency pattern was significant and very significant for other forage types, with Eucalyptus and Agricultural crops having a positive relationship compared to other forage types (Table 4.1). Vegetation units and Eucalyptus were there only non-significant in Limpopo. For Mpumalanga, Eucalyptus and Agricultural crops were very significant ($p<0.001$), compared to Suburban gardens and weeds, while Indigenous genera and Vegetation units were non-significant (Table 4.1). In contrast, both Eucalyptus and Agricultural crops were non-significant in the Norther Cape. Instead, Indigenous genera was very significant with a positive relationship, whereas Suburban plantings and Vegetation units had a negative significance. For the North West Province, Eucalyptus and Indigenous genera were non-significant compared to other forage types, which were either very significant (e.g. Agricultural crops) or significant (e.g. Vegetation units). In the Western Cape, Eucalyptus and Agricultural crops were the only forage types with very significant and significant frequencies respectively. However, Agricultural crops had a negative relationship compared to Eucalyptus.

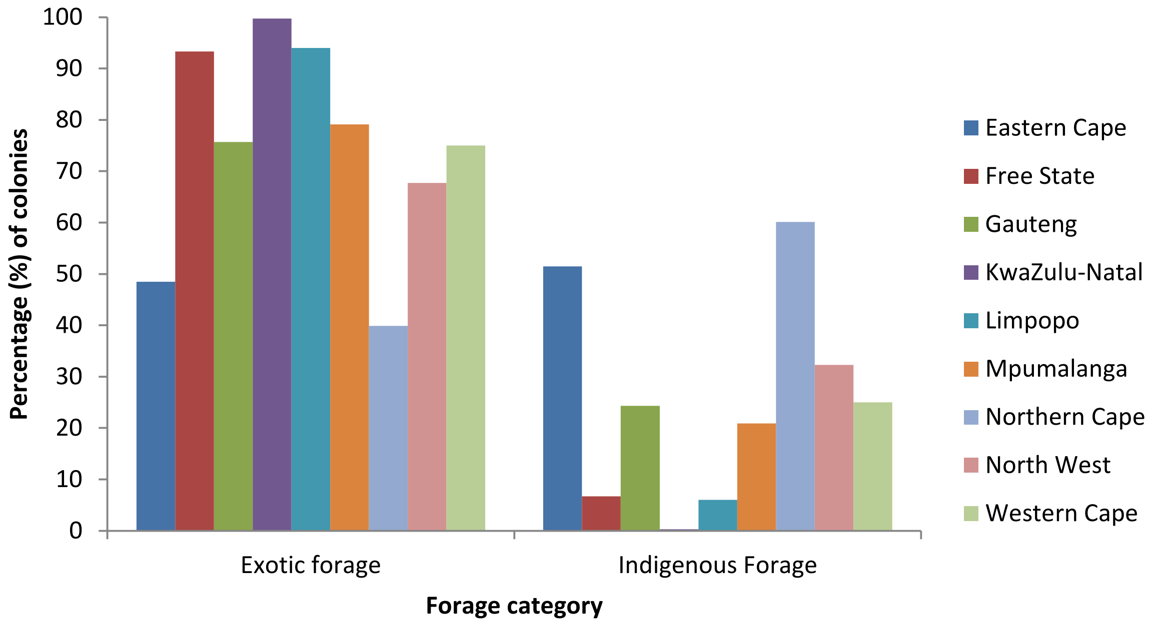

Figure 4.1: Percentage of colonies using different forage categories for honey crop.

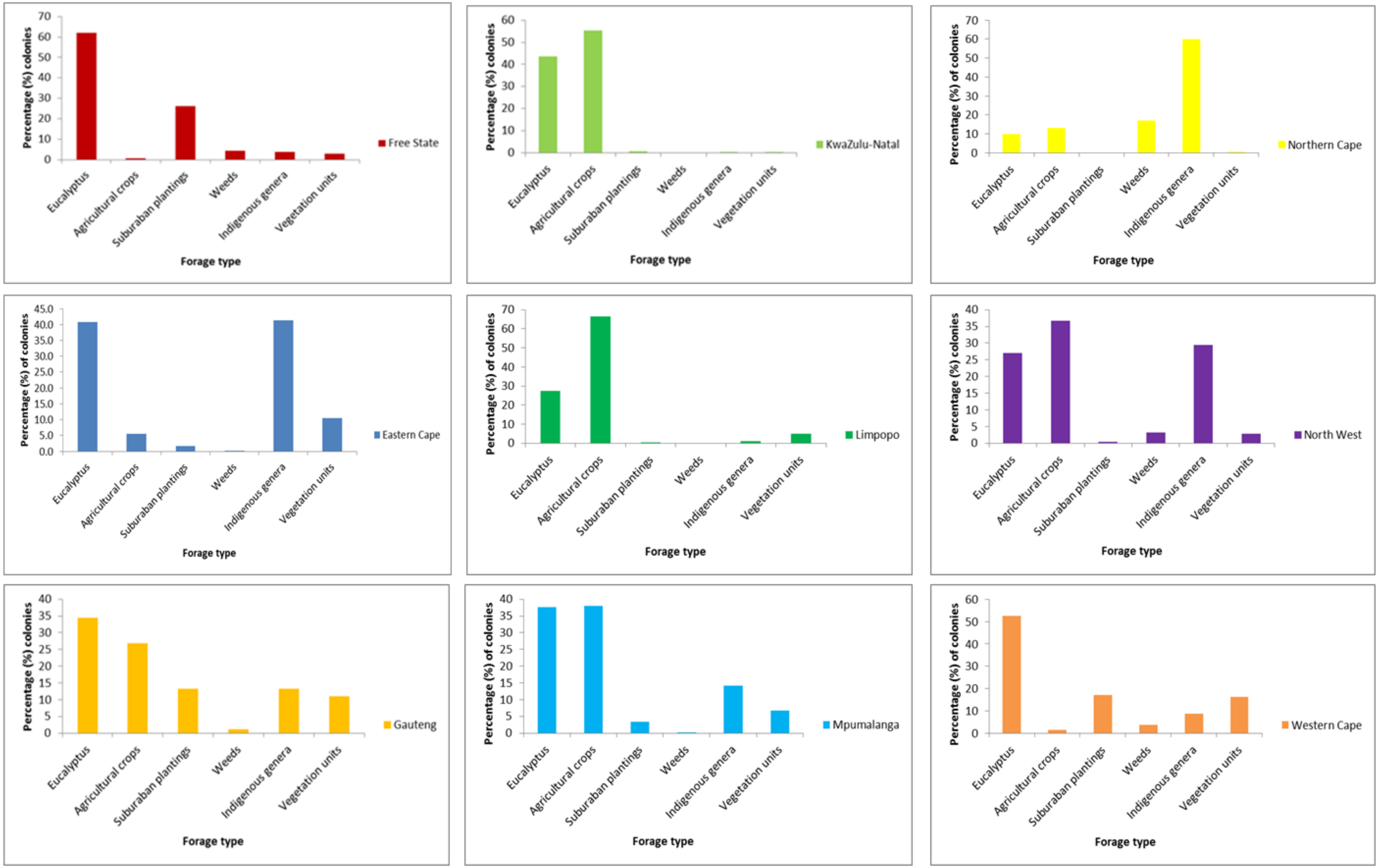

Figure 4.2: Percentage of colonies using different forage types for honey crop in each province.

Table 4.1: Forage type frequency variability for the different provinces. The relationship among the forage types is indicated by X^2 and the level of significance by P (p-value, denote by the significance at P < 0.05, 0.01 and 0.001 respectively) and the level of no significance (ns) denoted by α = 0.05.

Province	Eucalyptus		Agricultural crops		Suburban plantings		Weeds		Indigenous genera		Vegetation units	
	X^2	P	X^2	P	X^2	P	X^2	P	X^2	P	X^2	P
EC	34.7(+)	< 0.001	7.0(-)	ns	13.1(-)	< 0.05	16.8(-)	< 0.01	34.7(+)	< 0.001	2.0(-)	ns
FS	117.9(+)	< 0.001	12.9(-)	< 0.05	5.2(+)	ns	9.6(-)	ns	9.6(-)	ns	11.2(-)	< 0.05
GP	18.6(+)	<0.01	6.7(+)	ns	0.7(-)	ns	14.6(-)	<0.05	0.7(-)	ns	1.8(-)	ns
KZN	44.8(+)	<0.001	88.2(+)	<0.001	14.7(-)	<0.05	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01
L	7.7(+)	ns	146.0(+)	<0.001	16.7(-)	<0.01	16.7(-)	<0.01	14.7(-)	<0.05	8.2(-)	ns
MP	27.3(+)	<0.001	27.3(+)	<0.001	11.2(-)	<0.05	16.7(-)	<0.01	0.4(-)	ns	5.6(-)	ns
NC	2.7(-)	ns	0.8(-)	ns	16.7(-)	<0.01	0.0(+)	ns	112.7(+)	<0.001	16.7(-)	<0.01
NW	6.4(+)	ns	24.8(+)	<0.001	14.7(-)	<0.05	11.2(-)	<0.05	9.1(+)	ns	11.2(-)	<0.05
WC	73.5(+)	<0.001	11.4(-)	<0.05	0.0(+)	ns	9.8(-)	ns	3.6(-)	ns	0.0(-)	ns

() parenthesis indicates whether the significant level of the relationship slope was positive (+) or negative (-).

4.3.2 Significant forage sources across South Africa

Forage sources preferred for honey crop varied widely from one province to another, so was their importance. *Eucalyptus grandis* (Saligna gum) and *Eucalyptus camaldulensis* (River red gum) were the only two forage sources important for honey crop in five and four provinces respectively. They each supported between 5-34% of colonies in respective provinces (Table 4.2). In the Eastern Cape, Saligna gum was the most important honey crop, and the second most import honey crop in KwaZulu-Natal and Limpopo. *Helianthus annuus* (Sunflower) was a major honey crop in Gauteng and KwaZulu-Natal, supporting 15.1% and 36.7% colonies respectively. *Eucalyptus paniculata* (Grey ironbark) was the main honey crop in the Free State, while *Eucalyptus camaldulensis* (River red gum) in Mpumalanga and *Acacia/Senegalia mellifera* (Hook thorn) in the Northern Cape (Table 4.2). In Limpopo and North West Province, Macadamia spp. (Macadamia) was the primary honey crop, supporting 56.3% and 36.7% colonies respectively. For the Western Cape Province, *Eucalyptus cladocalyx* (Sugar gum) supported over 30% of the colonies with other forage sources supporting less than 11% each. *Prosopis* spp. was the only weed important for honey production in the Northern Cape, while Suburban plantings only featured in the Free State and Gauteng Province (Table 4.2). It is also worth mentioning that for Gauteng, Mpumalanga and the Western Cape, other forage species individually with less than a 5% contribution together accounted for a third or more of the forage used in these provinces.

Table 4.2: Honey crop forage sources supporting more than 5% of the colonies per province across South Africa's nine provinces

Forage type	Scientific name	Common name	Percentage (%) of colonies per forage source across provinces								
			EC (4329)	FS (205)	GP (1796)	KZN (8446)	L (1855)	MP (2977)	NC (5562)	NW (1361)	WC (23013)
Eucalyptus	*Eucalyptus grandis*	Saligna gum	29.9	-	-	34.1	25.4	15.1	-	8.7	
	Eucalyptus cladocalyx	Sugar gum	6.1	-	-	-	-	-	-	-	32.3-
	Eucalyptus sideroxylon	Black ironbark gum	-	17.5	-	-	-	-	9.9	-	-
	Eucalyptus/Corymbia ficifolia	Red flowering	-	13.6	-	-	-	-	-	-	-
	Eucalyptus paniculata	Grey ironbark gum	-	30.8	-	-	-	-	-	7.3	-
	Eucalyptus melliodora	Yellow box gum	-	-	11.7	-	-	-	-	-	-
	Eucalyptus camaldulensis	River red gum	-	-	8.3	-	-	20.8	-	5.5	10.5
Agricultural crops	*Helianthus annuus*	Sunflower	-	-	15.1	36.7	-	-	-	-	-
	Citrus spp.	Citrus	-	-	6.6	17	-	-	-	-	-
	Macadamia spp.	Macadamia	-	-	-	-	56.3	-	-	36.7	-
	Litchi spp.	Litchi	-	-	-	-	-	19.2	-	-	-
	Madicago sativa	Lusern/Lucerne	-	-	-	-	-	-	13.1	-	-
Weeds	Prosopis spp.	Prosopis spp.	-	-	-	-	-	-	16.7	-	-
Suburban plantings	Suburban gardens		-	26.3	13	-	-	-	-	-	-
Indigenous genera	*Scutia myrtina*	Cat thorn	28.9	-	-	-	-	-	-	-	-
	Acacia/Vachellia karroo	Sweet thorn	9	-	-	-	-	-	-	-	-
	Acacia/Senegalia mellifera	Hook thorn	-	-	-	-	-	-	28.6	14.7	-
	Ziziphus mucronata	Buffalo thorn	-	-	-	-	-	-	21	9.6	-
	Acacia/Vachellia tortilis	Umbrella thorn	-	-	-	-	-	-	6.3	-	-
Vegetation units	Eastern Cape Thicket		6.4	-	-	-	-	-	-	-	-
	Bushveld		-	-	11.1	-	-	-	-	-	-

	Coastal Fynbos	-	-	-	-	-	-	-	-	5.3
	Mountain Fynbos	-	-	-	-	-	-	-	-	5
***Others**	*Other forage sources	19.7	11.8	34.2	12.2	18.3	44.9	4.4	17.5	46.9

() Total number of colonies using respective forage sources in that province

- Percentage total of other forage source that does not support more than 5% of colonies individually in the province or might not be of use for honey crop in the province (see Appendix C for full listing)

* Total number of colonies supported by other forage sources whereby the individual forage source supports less than 5% colonies.

4.3.3 Number of localities used in relation to number of respondents and colonies kept

A total of 242 localities were listed for honey crop nationally. Western Cape (108) had the highest number of localities whereas Free State (3) was the lowest (Table 4.3). Limpopo, Northern Cape and North West had locality recordings below 10 compared to the other provinces (Table 4.3). The average number of colonies kept in total per locality, was less than 70 in the Free State and Gauteng, more than 300 in Limpopo, KwaZulu-Natal and the Northern Cape, while it was about 200 for all other provinces. The use of localities per respondent averaged below two (2), for all provinces except Mpumalanga (2.3). Free State and Limpopo had the lowest average locality use per locality with 0.6 and 0.2 respectively.

On average, Free State had more colonies per locality (33.3%) and Western Cape the lowest (1%). Other provinces had colony averages per locality below 20% (Table 4.3). It seems the average percentage of colonies per area is largely influenced by the total number of colonies reported per province and the total number of localities used for beekeeping. The more the colonies, the more area required to keep them. Similar trends can be observed for Limpopo, Northern Cape and North West (Table 4.3). Localities that supported more than 5% of the provinces' colonies for honey crop ranged from two (2) to seven (7). Gauteng was the highest with seven, followed by KwaZulu-Natal (6) and the other provinces recording below five.

Table 4.3: Average size of beekeeping operations (number of respondents, number of colonies kept, and number of forage localities, to nearest town) for honey production in South Africa's provinces.

Province	Respondents (n)	Total colonies reported	Total localities	Average number of localities per respondent	Average number of colonies per locality	Total localities supporting > 5% of colonies	Average % of colonies per locality
EC	14	4329	21	1.5	206	3	4.8
FS	5	205	3	0.6	68	3	33.3
GP	38	1796	50	1.3	36	7	2
KZN	18	8446	21	1.2	402	6	4.8
L	38	1855	6	0.2	309	3	16.7
MP	7	2977	16	2.3	186	5	6.3
NC	5	5562	8	1.6	695	2	12.5
NW	6	1361	9	1.5	151	2	11.1
WC	87	23013	108	1.2	213	4	0.9

4.4 Discussion

The generally poor historic documentation, with the exception of Hutton-Squire (2014), of the contribution of forage species to supporting managed honey bee colonies makes it difficult to identify the major honey crop forage across South Africa's provinces. Of the literature available and accessible, most forage records are restricted to the Western Cape Province (see Allsopp & Cherry 2004; Johannsmeier 2005; Brand 2009; Mouton 2011). Those forage sources documented by Johannsmeier (2001) are very general as they do not give account of specific use in different regions. However, the current findings show that honey production depends on diverse forage, as well as the importance of specific forage sources across provinces. That said, as a whole forage provided by exotic species dominates in honey production, particularly Eucalyptus and agricultural crops (see Table 4.3). For a given province, one particular forage source can be well used compared to other provinces but then its importance can vary markedly (e.g. Saligna gum is not equally important across all provinces). Here, localities of forage distribution were also observed to differ in number provincially with some areas supporting more colonies than others. This was also evident in the ratio of colonies per locality as well as average percentage of colonies per locality. Generally, provinces with fewer listed localities had high concentration of colonies per locality.

4.4.1 Forage types used for honey crop across South Africa

Several studies have documented both indigenous and exotic forage resources to be important for managed honey bee colonies for honey production (Johannsmeier 2001 & 2005; Allsopp & Cherry 2004; Conradie & Nortjé 2008; Mouton 2011; Hutton-Squire 2014). Findings from this study indicate that although both indigenous and exotic forage are used for honey crop, their significance is different. This was highlighted by the percentage of colonies supported by each and the significance of use frequencies for the different forage types. This goes against my hypothesis that forage for honey crop is used equally. Internationally, a combination of both indigenous and exotic forage has also been noted to be of importance for honey production and other beekeeping practices (Klein *et al*. 2002; Potts *et al*. 2003; Decourtye *et al*. 2010; Levy 2011). Within these indigenous and exotic forage types, the number of significant forage sources and vegetation units listed by beekeepers differed provincially. This is because beekeepers tend to use forage accessible to their colonies in a particular province at a given time (Hutton-Squire 2014). In this instance, it is clear that exotic forage is a major forage source for beekeepers in most provinces, and that there might not be alternatives that beekeepers are aware of besides these. At the same time, the dependence on a major exotic forage sources could make beekeeping vulnerable (honey production) to landscape management changes, and securing indigenous forage would not buffer such change (Allsopp & Cherry 2004; Levy 2011).

4.4.2 Percentage contribution of forage categories and forage types

The pattern of dependence on different forage types and sources is evident in the findings. Of importance is the observation of certain forage supporting more colonies than others at a given time. The importance of exotic forage for honey production is seen in seven of the nine provinces, an indication that that honey bees would forage on any plants available within the landscape irrespective of their status (Levy 2011). In the two provinces (Eastern and Northern Cape), where indigenous forage is favoured for honey crop over exotic, it is likely that beekeepers favour indigenous forage or it is widely available. According to Hutton-Squire (2014), the favourable use of indigenous forage in most parts of South Africa is primarily driven by the targeted removal of exotic and invasive plants species, thus indirectly forcing beekeepers to rely on indigenous forage for their beekeeping operations. Overall, exotic forage has always been the most reliable forage, Eucalyptus in particular (Johannsmeier 2001; Allsopp & Cherry 2004, de Lange 2013; Hutton-Squire 2014).

Unlike the Western Cape Province (see Turpie 2003; Allsopp & Cherry 2004; Conradie & Nortjé 2008; Mouton 2011, de Lange *et al*. 2013), there is lack of literature backing the dependence of beekeepers on Eucalyptus for honey production in the other provinces. However, Johannsmeier (2005); and Hutton-Squire (2014) alludes to the fact that Eucalyptus is South Africa's most extensively used honey bee forage source due to its reliable and dependable nectar and pollen provision. According to Conradie & Nortjé (2008), beekeepers in other provinces are slightly but not significantly dependant on gums as compared to those in the Western Cape Province. However, from the data shown here we see a strong dependence on Eucalyptus for most provinces. It is however only the Free State and Western Cape provinces that surpass the 50% mark. For the Western Cape, Allsopp &

Cherry (2004) indicated that 66% of the honey comes from Eucalyptus, while Conradie & Nortjé (2008) established that Eucalyptus makes up for almost 72% of the foraging sites for honey production. This is in contrast with my findings as Eucalyptus supports <55% of the colonies for honey crop. However, the use of Eucalyptus for honey crop in the Western Cape for honey crop is still significant as other forage types support less than 20% colonies each.

There was also a notable dependence in the use of agricultural crops for honey crop in Gauteng, Kwazulu-Natal, Limpopo, Mpumalanga and North West. This is consistent with documentations by Johannsmeier (2001) and (Morse & Calderone 2000) that various agricultural crops are important sources of nectar and pollen. Some crops (i.e. citrus and sunflower) are capable of yielding good nectar for viable honey production (Johannsmeier & Mostert 2001; Johannsmeier 2005). At the same time, suburban plantings and weeds do support a fair share of colonies for honey crop in respective provinces. Although South Africa is not a pro-urban beekeeping country compared to most European countries (see Moore & Kosut 2013), it is encouraging to see that desired honey crop forage is available and accessible in urban settings. The use of weeds as bee forage is well acknowledged (see Johannsmeier & Mostert 2001), however most are exotic and controlled for various management and conservation purposes. As such, their use and contribution to honey production in the beekeeping industry is less documented and perhaps underestimated by beekeepers.

Certain vegetation units have also been hypothesised to be good forage and honey crop for bees, particularly Fynbos vegetation in the Western Cape (Turpie *et al*. 2003). However, (Johannsmeier & Mostert 2001) caution that such vegetation units, weeds and indigenous genera are not reliable due to their sporadic flowering regimes and are rather used to bridge the forage shortage gaps during seasons. Although the historical documentation in the use of indigenous genera for honey crop is poor, this study captures their significance in both the Eastern and Northern Cape provinces. The substantial use of indigenous forage in these two provinces is likely due to their abundance and accessibility compared to exotics (Hutton-Squire 2014). Also, commercial beekeeping in these areas was not previously facilitated by the Forestry industry like the Western Cape (Johannsmeier 2001), and beekeepers use indigenous forage accessible for honey crop to a greater extent.

Eucalyptus grandis, *E. camaldulensis*, *E. cladocalyx* and *E. sideroxylon* that are historically extensively used forage (see Johannsmeier 2001; Johannsmeier & Mostert 2001; Johannsmeier 2005; Allsopp & Cherry 2004; Mouton 2011; de Lange *et al*. 2013) are also found here to be important honey crops. Worth noting here, is *E. cladocalyx* that supports 32% of the colonies in the Western Cape for honey crop. Johannsmeier (2004) and de Lange *et al*. (2013) concur that *E. cladocalyx* is typical summer forage crucial for colonies coming out of the pollination season. Therefore it provides essential forage when there is little to no Fynbos vegetation in flower. De Lange et al. (2013) further postulates that in any event that could possibly result in the loss of *E. cladocalyx* in the Western Cape as a bee forage source, it would cost beekeepers in the Western Cape $7.5m per annum in supplementary feeding for their colonies (sugar syrup and pollen substitutes) while an attempt to restore natural vegetation (Fynbos in this instance) to match its forage quality would amount to at least $20.2m per annum. Other Eucalyptus species such as *E. camaldulensis* and *E. melliodora* also support substantial colonies for honey crop. This highlights the important association of beekeeping practices with specific Eucalyptus species.

Other exotic forage preferences for honey production include agricultural crops citrus and sunflower which are generally favoured by bees for nectar (Johannsmeier 2001; Hoopingarner & Waller 2010) were found to be important honey crops for Gauteng and KwaZulu-Natal provinces. Their historic preference as bee forage is also strongly supported by Hutton-Squire (2014) who highlights their preferred use for colony maintenance and swarm trapping. In contrast, macadamia (Limpopo & North West) and litchi (Mpumalanga) which do not feature much historically for beekeeping purposes are here recorded to be important honey crops. These changes in preferred use are likely brought about by the marked increase in pollination services carried out by beekeepers who at times successfully harvest honey from those particular crops (Morse & Calderone 2000). Suburban plantings, which comprise of mostly exotic plants, also feature strongly in the Free State and Gauteng Province. Although it hasn’t been previous acknowledged for its role in any beekeeping practices as a category, the use of and dependence on exotics for bee forage is well documented (see Johannsmeier 2001 & 2005; Allsopp & Cherry 2004). It is therefore not surprising to witness its beekeeping value for honey production.

The use of *Scutia myrtina*, *Senegalia mellifera*, *Ziziphus mucronata* and *Vachellia karroo* for various beekeeping practices is widely acknowledged but typically their percentage contribution to honey production is not known (Johannsmeier 2001; Hutton-Squire 2014). Here, their relative importance for honey production is indicated by their ability to support substantial amount of colonies in certain provinces (Eastern Cape, North West and Northern Cape). Vegetation units such as Eastern Cape Thicket (Eastern Cape), Bushveld (Gauteng) and Coastal Fynbos as well as Mountain Fynbos in the Western Cape represent groupings of forage species. Beekeepers use these to describe bee forage they use in instances where they are unable to identify a single indigenous species that contributes to their honey crop or overall bee forage, instead referring to an average bee foraging radius around the apiary placed in natural vegetation stands. According to Mucina & Rutherford (2006), vegetation units within South Africa and the southern African region in general, represent extensive floral diversity capable of supporting a wide range of fauna. Here the floral diversity could easily offer diverse bee forage for beekeeping purposes (e.g. honey crop). For example, Turpie *et al*. (2003) eludes the importance of Fynbos vegetation for beekeeping during winter months. Fynbos honey is also very attractive on the market (Allsopp pers. comm. 2013). It is therefore not surprising that vegetation units are listed here by beekeepers for honey crop.

4.4.3 Number of localities used in relation to number of respondents and colonies kept

As early as 1920's, it was postulated that apiary sites in South Africa are widely different (i.e. environmental conditions) across localities (Attridge 1923). This also meant that different forage (species) will be available at different localities for honey crop and other beekeeping practices (e.g. colony maintenance). It is often the effort (travelling) to find desirable apiary sites on which to place their colonies that proves challenging for beekeepers (Johannsmeier 2001). Although honey bees themselves can forage at distances ranging from 0.8-13 km (Beekman & Ratnieks 2000), this has to be within landscapes of widely accessible and variable forage.

Localities used by different beekeepers for honey crop totalled 242 across the nine provinces. The spread of colonies across these areas were however extremely variable. The average percentage of colonies per locality show those provinces with higher number of colonies and fewer localities to place colonies end up with high stocking densities per locality. This trend was prevalent is provinces such at Free State, KwaZulu-Natal, Limpopo and Northern Cape. In contrast, Gauteng and Western Cape showed that having many localities for beekeeping reduces the stocking pressure for each locality. In both instances, the average number and percentage of colonies per locality were small (see Table 4.2). The number of respondents (beekeepers) does not seem to directly affect colonies per locality as some beekeepers own bigger beekeeping operations. For example, the Northern Cape had fewer beekeepers but a high number of colonies compared to other provinces.

Localities that support more that 5% of the province’s colonies were few as they represent high colony concentrations per locality. Provinces with many localities do not have to intensively stock up areas (e.g. Eastern Cape, Gauteng and Western Cape). This does not apply to the Free State and Limpopo, where half (if not all) of the localities listed supported colonies in this criterion. Therefore, the two provinces are likely to deal with intense competition for apiary should beekeeping operations in the provinces expand drastically.

4.5 Conclusion

Most studies fail to document forage types or sources generally valuable to beekeepers for honey production unless it is for specific plant species with interest for honey marketing purposes or for pollen analysis. In this chapter, I specifically documented honey crop plants used by beekeepers across the nine South African provinces. The availability of exotic versus indigenous forage sources varied considerably across provinces, so was their use preferences. As previously found, beekeepers overwhelmingly favoured exotic over indigenous forage sources across the majority of provinces. The Eastern and Northern Cape provinces are however the two exceptions indicating equal use. At the same time, the contribution and significance of various forage types and sources was different across provinces. In instances where a similar forage source was used in more than one province, its significance, based on the percentage of colonies supported, was different. Colony stocking rates were also variable in relation to average respondent per locality use and average percentage colonies per locality. Fewer colonies needed fewer localities, while fewer localities with high number of colonies resulted in more colonies per locality.

4.6 References

Allsopp, M.H. and Cherry, M. 2004. An assessment of the impact on the Bee and Agricultural industries in the Western Cape of the clearing of certain Eucalyptus species using questionnaire survey data. Pretoria (South Africa): National Government of the Republic of South Africa, Department of Water Affairs, Internal Final Report.

Allsopp, M.H. 2006. Analysis of *Varroa destructor* infestation of Southern African honey bee populations. MSc Dissertation, University of Pretoria, Pretoria.

Attridge, A.J. 1923. Beekeeping in South Africa. The Speciality Press of South Africa, Ltd. Cape Town, South Africa.

Beck, B.F. and Smedley, D. 1947. Honey and your health. Museum Press, London.

Beekman, M. and Ratnieks, F.L.W. 2000. Long-Range Foraging by the Honey-Bee, Apis mellifera L. *Functional Ecology* 14(4): 490-496.

Biesmeijer, J.C., Roberts, S.P.M., Reemer, M., Ohlemueller, R., Edwards, M., Peeters, T., Schaffers, A.P., Potts, S.G., Kleukers, R., Thomas, C.D., Settele, J. and Kunin, W.E. 2006. Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science* 313: 351-354.

Bilisik, A., Cakmak, I., Bicakci, A. and Malyer, H. 2008. Seasonal variation of collected pollen loads of honey bees (*Apis mellifera L. anatoliaca*). *Grana* 47: 70-77

Brand, M.R. 2009. The short term impact of a collection of commercial Cape honey bee (Apis mellifera capensis Esch.) colonies on invertebrate flower visitors within a near pristine Fynbos habitat in the Cape Floristic Region. MSc Dissertation, University of Stellenbosch, Stellenbosch.

Brodschneider, R. and Crailsheim, K. 2010. Nutrition and health in honey bees. *Apidologie* 41: 278-294.

CBI Market Survey. 2009. The honey and other bee products market in the EU. Retrieved: 12 August 2014. Retrieved from: http://www.fepat.org.ar/files/eventos/759630.pdf

Conradie, B. and Nortjé, B. 2008. Survey of beekeeping in South Africa. Centre for Social Science Research. Social Surveys Unit. CSSR Working Paper No. 221.

Crane, E. 1975. The flowers honey comes from. In Crane, E (Ed) Honey: a comprehensive survey, Heinemann; London, UK.

Crane, E. 1980. A book of honey. Oxford University Press.

DAFF. 2005. The honey trade: Forestry Sub-Sector Studies - Briefing 9. Retrieved: 12 August 2014: Retrieved from: http://www.daff.gov.za/doaDev/sideMenu/ForestryWeb/dwaf/cmsdocs/Elsa/Docs/FED/SubSector%20Honey%202005.pdf

Decourtye, A., Mader, E. and Desneux, N. 2010. Landscape enhancement of floral resources for honey bees in agro-ecosystems. *Apidologie* 41: 264-277.

de Lange, W. J., Veldtman, R. and Allsopp, M. H. 2013. Valuation of pollinator forage services provided by *Eucalyptus cladocalyx*. *Journal of Environmental Management* 125: 12-18.

D'Albore, R.G. and Piatti, G.C. 2004. Bee forage species in some tropical Countries (Cameroon, Mozambique, Rodriguez Islands and New Guinea): identification by honey pollen analysis. *Annali della Facoltà di Agraria - Università di Perugia* 55: 293-305.

ESAP. 2006. Institutional arrangements and challenges in market-oriented livestock agriculture in Ethiopia. Proceedings of the 14th annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia.

FAO. 2009. Bees and their role in forest livelihoods: a guide to the services provided by bees and the sustainable harvesting, processing and marketing of their products. Rome, Italy.

Gathmann, A. and Tscharntke, T. 2002. Foraging ranges of solitary bees. *Journal of Animal Ecology* 71: 757-764.

Herold, E. 1970. Heilwerte aus dem Bienenvolk (Helath substances from the hive). Ehrenwirth, Munich.

Hoopingarner, R. A. and Waller, G. D. 2010. Crop pollination. In: Graham, J. M. (Ed.), The hive and the honey bee, Dadant & Sons, Inc. Hamilton, Illinois.

Hutton-Squire, J.P. 2014. Historical Relationship of the Honey bee (*Apis mellifera*) and its forage; and the current state of Beekeeping within South Africa. MSc Dissertation, University of Stellenbosch, Stellenbosch.

Johannsmeier, M.F. 2001. Beekeeping in South Africa. Plant Protection Handbook No. 14, Agricultural Research Council, Pretoria.

Johannsmeier, M. F. and Mostert, A. J. N. 2001. South African nectar and pollen flora. In: Beekeeping in South Africa, 3rd edition. Plant Protection Research Institute, Handbook No. 14. Agricultural Research Council, Pretoria.

Johannsmeier, M.F. 2005. BEEPLANTS of the South-Western Cape. Nectar and pollen sources of honey bees (revised and expanded). Plant Protection Research Institute Handbook No. 17, Agricultural Research Council, Pretoria.

Keasar, T. and Shmida, A. 2009. An evaluation of Israeli forestry trees and shrubs as potential forage plants for bees. *Israel Journal of Plant Sciences* 57: 49-64.

Klein, A.M., Steffan-Dewenter, I. and Tscharntke, T. 2002. Effects of land-use intensity in tropical agroforestry systems on flower-visiting and trap-nesting bees and wasps. *Conservation Biology* 16: 1003-1014.

Klein, A.M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I, Cunningham, S.A., Kremen, C. and Tscharntke, T. 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society* 274: 303-313.

Levy, S. 2011. What's best for bees. *Nature* 479: 164-165.

Moore, L.J. and Kosut, M. 2013. Buzz: Urban beekeeping and the power of the bee. NYU Press, New York.

Morse, R.A. and Calderone, N.W. 2000. The value of honey bees as pollinators of U.S. crops in 2000. *Bee Culture* 128: 1-14.

Mouton, M. 2011. Significance of Direct and Indirect Pollination Ecosystem Services to the Apple Industry in the Western Cape of South Africa. MSc Dissertation, Stellenbosch University, Stellenbosch.

Mucina, L. and Rutherford, M. C. 2006. The Vegetation Map of South Africa, Lesotho and Swaziland. SANBI, Pretoria.

NAMC Report. 2008. 3rd Draft Report. A section 7 committee investigation. The South African Beekeeping Industry. Pretoria, South Africa.

Pirk, C.W.W., Human, H., Crew, R.M. and vanEngelsdorp, D. 2014. A survey of managed honey bee colony losses in the Republic of South Africa – 2009 to 2011. *Journal of Apicultural Research* 53(1): 35-42.

Potts, S.G., Vulliamy, B., Dafni, A., Ne'eman, G. and Willmer, P. 2003. Linking bees and flowers: How do floral communities structure pollinator communities? *Ecology* 84(10): 2628-2642.

Potts, S.G., Vulliamy, B., Roberts, S., O'Toole, C., Dafni, A., Ne'Eman, G. and Willmer, P. 2005. Role of nesting resources in organising diverse bee communities in a Mediterranean landscape. *Ecological Entomology* 3: 78-85.

Anonymous. 2014. Wirld honey market: South African honey prices. *South African Bee Journal* 86(2): 340-341.

Samnegård, U., Persson, A.S. and Smith, H.G. 2011. Gardens benefit bees and enhance pollination in intensively managed farmland. *Biological Conservation* 144: 2602-2606.

Situation Analysis of Beekeeping Industry. *Date unknown*. Situation Analysis of the Beekeeping Industry in Botswana, Lesotho, Malawi, Mozambique, South Africa, Swaziland, Zambia and Zimbabwe. Retrieved: 12 August 2014: Retrieved from: http://www.beekeeping.com/articles/us/beekeeping_regional_situational-analysis.pdf

Strauss, U., Humana, H., Gauthier, L., Crewe, R.M., Dietemann, V. and Pirk, C.W.W. 2013. Seasonal prevalence of pathogens and parasites in the savannah honey bee (Apis mellifera scutellata). *Journal of Invertebrate Pathology* 114: 45-52.

Thomas, D., Pal, N. and Rao, K.S. 2002. Bee management and productivity of Indian honey bees. *Apiacta* 3: 1-5.

TIPS, 2005. Honey trade information brief. Retrieved: 12 August 2014. Retrieved from: http://www.sadctrade.org/files/Honey%20Trade%20Information%20Brief.pdf

Turpie, J. K., Heydenrych, B. J. and Lamberth S. J. 2003. Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation strategies. *Biological Conservation* 112: 233-251.

vanEngelsdorp, D. and Meixner, M.D. 2010. A historic review of manged honey bee populations in Europe and the United States and the factors that may affect them. *Journal of Invertebrate Pathology* 103: S80-S95.

Weston, R. J., Mitchell, K.R. and Allen, K.L. 1999. Antibacterial phenolic components of New Zealand manuka honey. *Food Chemistry* 64(3): 295-301.

White, J.W. and Landis, W.D. 1980. Honey composition and properties. Beekeeping in the US Agriculture Handbook Number 335. US Department of Agriculture, Washington, DC.

Chapter 5
The use of managed honey bee for pollination services in South Africa: the supply versus the demand

5.1 The importance and value of managed honey bee pollination

Honey bees remain the most economically valuable pollinator of most crops worldwide (Watanabe 1994; Klein *et al.* 2007; Garibaldi *et al.* 2013). According to Southwick & Southwick (1992), the yields of some fruit, seeds and nut crops decrease by more than 90% without managed bee pollination. In agricultural areas where natural vegetation is degraded or non-existent thereby limiting wild pollinator populations, managed honey bee hives are basically the only solution for farmers to ensure adequate crop pollination (Morse 1991; Richards 2001; Klein *et al*. 2007; Allsopp *et al*. 2008). Although honey bees are the best and most easily managed pollinators, they are not effective pollinators for all crop types (Cane 1997; Westerkamp & Gottsberger 2000). There are however three caveats with this statement namely, manged honey bees are often ten times more abundant than the most abundant wild pollinator species; second, for the bulk of traditional cross-pollinated crops managed honey bees are sufficient to ensure required yields (Calderone 2012); and third with global declines in pollinators due to land degradation and habit destruction (Ricketts *et al*. 2008; Winfree *et al*. 2009), managed honey bees are likely the only pollinators that can guarantee pollination to a wide variety of crops currently and in the future (Morse 1991; Aizen & Harder 2009; Calderone 2012).

Modern (intensive) agriculture is increasingly dependent on managed pollinators for commercial crop pollination (Richards 2001), with commercial pollination being the most important derived value of commercial beekeeping globally (Morse & Calderone 2000). The sustainability of agricultural practices pertaining to food security is therefore dependent on the pollination services provided by managed honey bees (although wild pollination services are usually heralded as such). It is also for such reasons that the value added by pollination services is an increasingly important component of agricultural Gross Domestic Product (GDP) in most countries (see Lautenbach *et al*. 2012). This makes the honey bee the single most important crop pollinator species (McGregor 1976). Although some argue that food security would not be compromised should insect pollinators such as honey bees disappear (Ghazoul 2005), it is however not certain as to what extent the diverse human diet will be affected or altered.

The value of managed pollinators in commercial crop pollinations has been estimated in many countries using different methods, and the results thereof are highly dependent on the method used (see Morse & Calderone 2000; Allsopp *et al*. 2008; Gallai *et al*. 2009; Calderone 2012; Breeze *et al*. 2014). It is however certain that as the area of these insect pollinated crops increases, so will the need of pollination services (Aizen *et al.* 2008; Aizen *et al* 2009; Aizen & Harder 2009; Breeze *et al*. 2014), and consequently the value of managed pollinators (Calderone 2012). However only a handful of countries have attempted to estimate and quantify the value of pollination services carried out by honey bees (see FAO 2009).

In South Africa, the contribution of managed honey bees to crop production was found to be between $28.0-122.8 million (Allsopp *et al*. 2008). This value was estimated only for the deciduous fruit industry in the Western Cape, however, meaning that it would increase if other crops are taken into account. Either way, these values highlight the importance of honey bee pollination services to agricultural crop production or the potential increase in demand for such services in the future (Aizen *et al*. 2008).

5.1.1 The supply of managed honey bees for commercial crop pollination

The population of managed honey bees have increased globally, even though decreases are continuously reported at local and regional scales (vanEngelsdorp & Meixner 2010). This increase, however, falls short of the global growth in the production of pollinator-dependent crops (Aizen & Harder 2009). This raises the fear of compromised food security and the loss of monetary value if, overall, insect pollinators (specifically managed honey bees – see earlier references) were absent (Gallai *et al*. 2009). Breeze *et al*. (2014), also indicates that a reduction in the availability of pollinators for pollinator dependent crops may have other consequence yet to be predicted or valued. These can range from change in market trends to dietary preference and consumer behaviour.

In an event of sustained losses of honey bees, growers would be forced to use other pollinators (i.e. non-*Apis*) or manual pollination methods (see Allsopp *et al*. 2008). Most of such non-*Apis* species are as efficient as honey bees (Klein *et al*. 2007). Furthermore, the agricultural system on the farm land would have to support their nutritional needs and nesting requirements (Potts *et al*. 2005; Carvalheiro *et al*. 2010). In areas where natural habitat remains intact and well associated with insect biodiversity, pollinator-dependant crops are likely to have good yield and quality produce (Winfree *et al*. 2009). In essence, the use of managed non-*Apis* pollinators may be possible for some crops under ideal conditions (untransformed landscapes) but not others (Breeze *et al*. 2014).

Seasonally, growers bring in rented hives to pollinate their crops. However, charges per hive and stocking rates per hectare vary considerably from crop to crop (Morse & Calderone 2000; Johannsmeier 2001). In both these studies, recommendations on stocking rates for adequate pollination per crop are outlined but growers still do under or over stock at times depending on their preferred method of practice for desired yields and crop quality. Most of these recommendations are outdated and still debatable as they lack sufficient research data (Allsopp *et al.* 2008; Mike Allsopp pers. comm. 2013). This has also led to speculations and mismatches in the supply and demand of managed honey bee pollination services across most countries (Sumner & Boriss 2006; Calderone 2012). In some countries, such estimations or data does not even exist (i.e. South Africa), subsequently making it difficult to justify any speculations of a managed honey bee shortage for pollination of insect dependent crops.

As in most countries globally, managed honey bees are an integral part of the agricultural sector in South Africa, with growers relying on rented hives for crop pollination (Allsopp et al. 2008; Mouton 2011; de Lange et al. 2013; Hutton-Squire 2014; Melin *et al*. 2014). The deciduous fruit industry in the South-Western Cape and the vegetable seed (e.g. onion) growing region of the Klein and South Karoo (Western Cape) are two well acknowledged sectors making use of the pollination services (see Johannsmeier 2001; Allsopp & Cherry 2004, Allsopp *et al*. 2008; Mouton 2011; de Lange *et al*. 2013; Brand 2014). Although other fruit and vegetable growing areas across the country do make use of rented bee hives for pollination, these two production areas have the biggest, and continuously increasing, demand (Mike Allsopp pers. comm. 2014). According to Allsopp & Cherry (2004) and de Lange *et al.* (2013), the deciduous fruit industry needs more than 30000 bee colonies annually to meet pollination demands, although annual crop pollination in the Western Cape may require as much as 60000 managed colonies (Mike Allsopp pers. comm. 2014). Of particular importance is the fact that these two agricultural regions rely only on *Apis mellifera capensis* subspecies which is restricted to the Western Cape Province, prohibiting the movement of managed colonies due to the restrictions for crossing the hybrid zone (see Johannsmeier 2001; Pirk *et al*. 2014). This makes the supply of managed hives for crop pollination in this region very critical, as bees from other provinces cannot be sourced. Any shortfalls in pollination services for these regions would thus have devastating outcomes for crop production.

Economically, the total value added to the country's agricultural sector by managed honey bee pollination is estimated around R12-14 billion per annum (Mike Allsopp pers. comm. 2014). This accounts for crops such as vegetable seeds, deciduous fruit, sub-tropical fruit, melons, berries, oilseed crops, nuts, cucurbits and beans. The deciduous fruit industry alone has an estimated annual turnover of $501 million (Allsopp *et al*. 2008). The estimated value of managed honey pollination to the deciduous fruit industry can reach up R 828 million annually (NAMC Report 2008). This industry has export earnings of about R5 billion per annum and supports an estimated 170,000 jobs (Allsopp & Cherry 2004). Other crops benefitting from managed bee pollination with substantial gross production values (GPV) included onion seeds with R267 million (~$21.8 million) (Brand 2014), subtropical fruit and nuts with an estimated R950 million (http://gteda.co.za/), canola (<R350m, DAFF 2013), carrot seed (<R40m, DAFF 2013), dry beans (<R50m, DAFF 2013), cabbage seed (<R20m, DAFF 2013), macadamia (<R30m, DAFF 2013), sunflower seed (<R200m, DAFF 2013).

Hive rentals for crops vary from region to region, farmer to farmer and crop to crop. At times, payment for hives is not required depending on the arrangement between the beekeeper and grower (Clark 2012). Although most local/regional beekeeping associations do give advice and set standards for pollination hives, beekeeper-farmer agreements, and remuneration (see http://www.sabio.org.za), most beekeepers make individual choices that is to the benefit of their business. At the forefront of all this, is the secretiveness in arrangements and agreements of pollination contracts. This translates to beekeepers not wanting to divulge which growers they rent their hives to, and vice versa. In turn, the statistics for hive rentals annually for various crops are “never” available for public or research use. At the same time, most growers are not affiliated to any associations, especially for more novel crops. They are therefore not obliged to divulge any information regarding their planting area(s) or the use of managed hive for pollination services, if any. Besides recent interventions on pollination services research on apples, hybrid onion seed and sunflower by the Global Pollination Project, there is generally a lack of investment in proper coordinated research on crop pollination services in South Africa. This has led to poor to non-existent records on hive rentals for various crops. The stocking rates per hectare or even cultivar for some of the crops are based purely on outdated international literature. Yet, on an annual basis in some regions, growers are in uproar due to possible shortages of managed hives for their crops.

Understanding the extent to which the South African agricultural sector is dependent on managed honey bee pollination is crucial. This translates as the number of crop hectares that require renting colonies. Although the total area of land under cultivation from 1900 to 1990 has increased by 56% globally (Ramankutty *et al*. 2002), increases at a local are difficult to determine. Future growth projections are also not available as most companies are reluctant to share information. In turn, this makes it difficult to can relate the current and future supply of managed honey bee colonies for crop pollination. Furthermore, this is not limited to South Africa. Most European countries also lack good records on pollination supply and demand due to the uneven spread and quality of data present (Breeze *et al*. 2014). However, these datasets are still far better than what is available for South Africa. Here, unlike in Europe, individual sectors manage their own information, while growers at ground level administer different planting and hive rental practices (both of which affect the demand for managed honey bee hives) and such information is never publicly available for majority of the sectors. At times, the relevant authorities are also not willing to divulge it. Of great importance is the need for beekeepers and growers to record and report on pollination practices – so that South Africa can have some idea of the real pollination demand and real pollination usage

Consequently, the main aim of this chapter is to determine for all nine South African provinces: 1) the proportion of managed honey bee colonies used for commercial pollination and which crops they pollinate; 2) the pollination demand from growers for managed honey bee colonies based on declared planting areas; and 3) which forage resources these colonies depend on during pollination – these may also be the actually crops being pollinated – particularly in instances where such forage is agricultural crops. Therefore, the hypothesis tested here is that agricultural crops are the major forage source for all nine provinces during pollination.

5.2 Methods

5.2.1 Use of managed honey bees for crop pollination

The number of colonies used for pollination was calculated from disclosed values given in the Forage use beekeeper questionnaire (Appendix A). Section A and B of the forage use beekeeper questionnaire (outlined in Chapter 2) was used to capture the percentage of managed colonies used by each beekeeper (respondent) for commercial crop pollination. In Section A, beekeepers gave the total number of colonies they own and in Section B indicated the percentage of these used for commercial pollination. Following on from this disclosed data, beekeepers gave a break down, in percentage, the colonies used for pollination for each crop. The crop types were pre-listed, but beekeepers could add any crops they provide pollination services for if not included on the list.

To determine the number of colonies used for crop pollination per beekeeper, the percentage given for the entire pollination services was reverted to colony numbers. For example, if a beekeeper owns 1000 colonies and uses 40% for commercial crop pollination, then the number of colonies would be 400 using the following equation (Equation 4):

$$\textbf{\textit{Relative colonies used for pollination}} = (\textbf{\textit{Percentage Colonies used for pollinatin}} \div \mathbf{100}) \times \textbf{\textit{Total colonies owned}}$$

Because further percentages for colonies pollinating respective crops were given from the main colony pollination percentage (determine in equation 4 above), their relative numbers also had to be determined. For example, if we take the same beekeeper from the above example, and he indicates that of 40% of his colonies used for crop pollination, 90% is for Subtropical fruits and 10% for vegetables, this equates to 360 and 40 respectively using equation below (Equation 5):

$$\begin{aligned}&\boldsymbol{Relative\ colonies\ for\ pollinating\ a\ specific\ crop}\\&\quad= (\boldsymbol{Percentage\ Colonies\ used\ for\ pollinating\ this\ crop} \div \mathbf{100})\\&\quad\times \boldsymbol{Relative\ colonies\ usedfor\ pollinaion}\ (\boldsymbol{Derived\ from\ Equation}\ \mathbf{4})\end{aligned}$$

All relative colony numbers worked out for the respective crops should always add up to the relative colonies for pollination initially derived in Equation 4.

5.2.2 The grower crop pollination demand and crop forage supply for managed honey bee colonies based on planting area

Various crop sectors believed to be benefitting from managed honey bee crop pollination were approached by means of a formal request and structured questionnaire to gather data on the number of managed honey bee colonies required in their sectors (see Appendix D). These were either individual growers or associations representing a certain sector (i.e. vegetable growers). Where necessary, meetings were arranged, telephone calls made and e-mails sent for follow ups on the initial request.

First, growers were asked to provide information for their past, current and projected plantings of their respective crops. Specifically, the total hectares of each listed crop that was planted in South Africa in 2003, 2008 and 2013, and the projected hectares of each crop in 2018 was requested. Planting areas were required to be broken down into provinces for each respective year. Filled examples of Table 1 and 2 of Appendix D were given to assist in supplying the correct information. The reason for any increase or decrease in planting area for a crop in respective years cannot be accounted for in this study since the effect thereof (i.e. environmental condition or change in market trends) was not assessed.

Second, growers were asked to provide information on the use of commercial pollination services for listed crop types in 2013. In addition, growers had to also indicate any possible gratuitous pollination of their crops as a result of the forage use of beekeepers. Pollination service use information for each crop type was to be divided as follows: 1) the numbers of hectares of that crop that are pollinated by rented managed honey bee colonies; 2) the numbers of colonies per crop type that are introduced without payment by beekeepers; 3) the numbers of hectares that are pollinated by managed but non-commercial/not rented honey bee colonies ('own bees'); and 4) the numbers of hectares that are pollinated by wild honey bees or other pollinators (Table 3 in Appendix D). However, early responses indicated that information on the use of managed honey bees for crop pollination was either not existent, unreliable or that growers were not willing to share this information. Data on the extent of managed honey bee pollination services supplied could thus not be determined.

Due to the absence of this information, managed honey bee stocking density was instead used to indicate the number of managed honey bee colonies that would be required to pollinate each crop. For crops that managed honey bee stocking densities used during pollination was not available, I adopted recommended standard stocking rates for respective crops from Morse & Calderone (2000) and Johannsmeier (2001). If rates differed between these sources, Johannsmeier (2001) was given preference due to higher relevance in South African agricultural context. Globally, recommended stocking rates are used to estimate each crop's demand for pollination services (Allsopp *et al*. 2008; Breeze *et al*. 2014) despite errors that could arise. Consequently, the minimum number of managed honey bee colonies required to provide adequate pollination per crop annually was calculated by multiplying the total crop planting hectares with the minimum recommended hive per hectare stocking rate (to achieve adequate pollination). Growers at times use more colonies per hectare than the recommended rates but only minimum requirements are used here since no exact stocking rates could be obtained from growers for all crops.

Crops that were documented not to make use of commercial pollination but instead provide good bee forage; the same methods were used to calculate the number of colonies that can be supported based on available planting information for these crops.

5.2.3 Forage that managed honey bees depend on during pollination

The forage use beekeeper questionnaire survey outlined in Chapter 2 was used for collecting forage use data using, only Section A (number of colonies) and E (forage use patterns). In section A, beekeepers had to indicate the total number of colonies they actively manage. For the forage type and use data table, Section E, beekeepers were provided with an outlined list of various plants known to be used by honey bees as forage in South Africa (Johannsmeier 2001 & 2005; Allsopp & Cherry 2004; Mouton 2011), as well as the option to add other plants when indicating forage use (Chapter 2). In the pollination column (Table in Section E), beekeepers had to indicate the average percentage of their colonies that benefit from a single forage type/source (summing up to 100% for each beekeeper).

The recorded average percentage of colonies dependent on a forage source thus indicated the importance of that particular forage source to colonies during pollination. For estimates of colony numbers supported during pollination, the average colony percentages given are reverted to relative colony numbers. For example, if a beekeeper indicates that he has an ***x*** number of colonies (in section A); then in section E he indicates that on average, y% of his ***x*** colonies use ***forage b*** during pollination, then the following equation (Equation 6) was applied:

$$\begin{aligned}&\boldsymbol{Relative\ number\ of\ colonies\ supported\ for\ pollination\ by\ forage\ b}\\&\quad= (\boldsymbol{Average\ percentage\ of\ colonies\ supported\ by\ forage\ b\ \div 100})\\&\quad\times \boldsymbol{Total\ colonies\ owned}\end{aligned}$$

Forage sources of common use amongst beekeepers within the same province were counted only once with all colonies associated with that particular forage source added. Chi-square was used to establish whether the frequency of use between the various forage categories were the same or has any level of significance. The significance of differences were determined by Likelihood Ratio X^2 analyses for the six forage types for each province. Similar to Chapter 4, Bloom periods are not discussed in the body of this chapter but listed in Appendix C. For forage localities, I give account of the total localities used per province and highlight localities that supported more than 5% colonies.

5.3 Results

5.3.1 Use of managed honey bees for crop pollination

The number of hives used for commercial crop pollination per crop and province ranged between 86 and 14772 (Figure 5.1). In total, 23344 (46.6%) hives were used for pollination nationally. Free State was the only province with no colonies used for commercial crop pollination. The Eastern Cape, Gauteng and Limpopo each had less than a thousand hives used for pollination compared to the other five provinces (Figure 5.1). The Northern and Western Cape recorded highest use of hives for crop pollination, with 4229 and 14772 colonies used respectively. For crop pollination, hive use varied considerably among provinces and crop types. In most provinces, colonies were used for the pollination of vegetable seeds, subtropical fruits, oil seeds, nuts and melons (see Figure 5.1). Crops making use of more than 40% of the colonies used for pollination included: subtropical fruits in the Eastern Cape and Mpumalanga; oil seeds in Gauteng, KwaZulu-Natal, Northern Cape and North West; melons in Limpopo; and deciduous fruits in the Western Cape (Figure 5.1). Of particular interest were oil seeds in KwaZulu-Natal and Northern Cape, as well as deciduous fruits in the Western Cape that were pollinated by more than 80% of the colonies used for pollination services. In contrast, crops such as butternut and lucerne were pollinated by >5% of the colonies in their respective provinces (Figure 5.1).

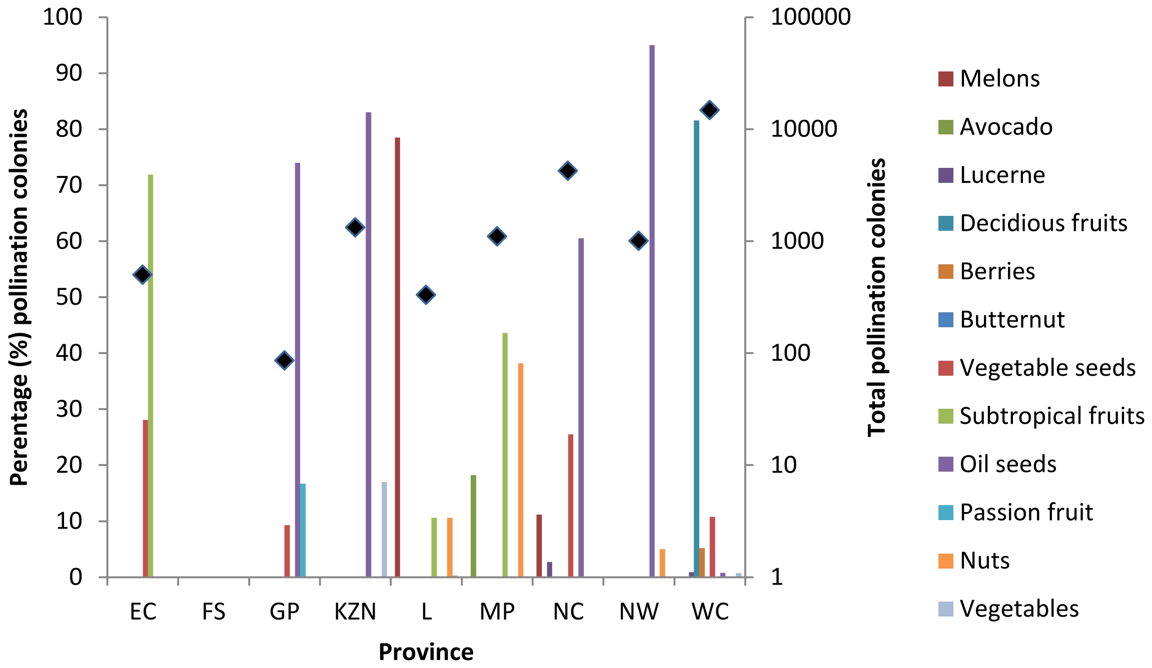

Figure 5.1: Percentage of colonies used for pollination of various crops across the nine provinces (indicated on the left y-axis) and total number of colonies used for pollination in each province (indicated on the right y-axis). The filled diamonds indicate the total number of managed colonies used for pollination per province.

5.3.2 Crop planting area and crop pollination demand

Crop planting areas

Planting data for deciduous fruits was marked by fluctuations for the years 2003 to 2013. Planting projections for 2018 indicate increases for Apricot and Plum, but not the other crops (Table 5.1). Apples and plums experienced their lowest planting area in 2008, compare to Pears and Apricots that had low planting area in 2013. Nectarines and Peaches had a variable annual increase from 2003-2008, varying from at least 28-300 and 100-500 hectares for different years respectively. Plum production experienced a decrease of 481 hectares in 2008 before peaking again in 2012. Projections for 2018 indicate the biggest ever planting area for Plums since 2003 (Table 5.1).

Almonds were the only crop with planting data for 2003-2013. In all these years, Almond planting remained at 100 hectares. For 2013, avocado had the biggest planting area compared to granadilla, litchi and mango. That is a total area of 4706 hectares, with granadilla, litchi and mango having a combined 3695 hectares (Table 5.1). Macadamia also had data for 2013 only, and the total planted area was 5749 with no projections available for 2018.

The area planting for carrot, onion and sunflower increased from the 2003 to 2013. There was an annual average increase of 86.6 hectares for Onion 2003 to 2013 (Table 5.1). That is over 400 hectares for every five years. The plating area for carrot increased slightly from 2003-2008, while there was little difference from 2008-2013 (Table 5.1). Sunflower experienced a small increase (56 hectares) from 2003-2008 as opposed to the greater increase in area (330 hectares) from 2008-2013. The Cherry production area had the highest increased from 2003-2008. In this period there was an additional 131 hectares, compared to the 2008-2013 period (Table 5.1). Lucerne experienced a decline of 28 hectares during 2003-2008 then a sharp increase of 733 hectares from 2008-2012. For leeks, the planting area had a difference of 20 hectares for 2008-2012 (Table 5.1). Both canola and citrus had continuous increase in planting areas for the year 2003 to 2012 and 2003-2013 respectively. For citrus, the biggest increase was from 2008-2012 with 3713 hectares. The planting area for canola increased by 39760 from 2003-2013, with the highest increase experienced from 2012-

2013. This was an increase of 24180 hectares. Projections for 2018 also indicate additional expansion in planting area for canola by an additional 27440 hectares (Table 5.1).

Crop pollination demands

The number of hives required for pollination is subjective to the number of hectares planted. Hives for pollination increases or decreases according to the planting area. With an average stocking rate of 2 hives/ha, Apples were estimated to have had their highest pollination demand in 2013. This is a total of 44998. The demand is however projected to decrease in 2018 (Table 5.1). In contrast, Pears would have their lowest pollination demand in 2013. A decrease in pollination demand is also forecast for Pears in 2018 (Table 5.1). That is a decrease of 1076 (2.2%) hives from the year 2013. Apricots experienced a decrease in pollination demand from 2003-2013, while Nectarines and Peaches had an increased demand from 2003-2013. Projections for pollination demands in 2018 indicate an increase for Apricots opposed to Nectarines and Peaches (Table 5.1). However, the increase is minimal (94 hives). Plums have the highest stocking rate among the deciduous fruits (6 hives/ha), and the pollination demand has increased since 2012 and is bound to continue into 2018 (Table 5.1).

The planting area for almonds remained constant from 2003-2013, meaning that the supply of hives for pollination had remained at 500 the entire period. Granadilla pollination would have required 260 hives in 2013, whereas litchi, avocado, mango and macadamia needed 882, 9412, 8982 and 11498 pollination hives respectively. The continuous increase in planting areas for onion, carrot and sunflower resulted in the increased number of hives for pollination from 2003-2013. For onions, the number of pollination hives increased from 645 in 2003 to 7250 in 2013. Similar increases were noted for carrot and cauliflower, whereby increase were from 710-875 and 10440-12756 for 2003 t0 2013 respectively.

The pollination demand for cherries increased from 132 hives in 2003 to 454 hives in 2008, before a slight decrease of four hives in 2013. Pollination hive numbers for lucerne were the lowest during 2008 and highest in 2013 (Table 5.1). Leeks also recorded an increase in pollination demand from 2008 to 2012. The increase was a total of 120 hives for the four years. Worth noting is the overall inconsistencies of data for most crops from one year to another. This in particular pertains to subtropical fruits and therefore limits proper comparisons in production area and pollination changes annually, and subsequently future projections (Table 5.1).

Both citrus and canola are subject to scrutiny regarding their pollination requirements or the lack thereof. Although planted at large scales, they serve mostly as bee forage as opposed to their pollination need. I still include both crops in this section, but strictly as bee forage crops and indicate their planting scale (Table 5.1) as well as potential colonies supported (Figure 5.2). The value of potential colonies is worked out using the minimum hives required per hectare as illustrated in Table 5.1. Citrus currently supports more than 6000 colonies with no future projections available (Figure 5.1 & Table 5.1). In contrast showed an increase in the number of colonies supported since 2003 and this is set to continue into 2018 (Figure 5.1 & Table 5.1).

Colony demands from year 2003 to 2018 are also summarised in Figure 5.3 below. Although sunflower and pasture (leeks and lucerne) lack projection data, the current demand is steady and expected to remain the similar throughout. Vegetable seeds (onions and carrot) experienced a sharp increase in pollination demand from 2003 to 2012. Nuts (almonds and macadamia) had a consistent demand until 2012 when it drastically increased in 2013. Deciduous fruits (apple, pear, apricot, nectarines, peach and plum) are shown here to experience relatively small fluctuations over time. Other crops (e.g. berries) were excluded in this summary as their managed honey bee demands were below 10000 or had only a single year of data (e.g. subtropical fruits).

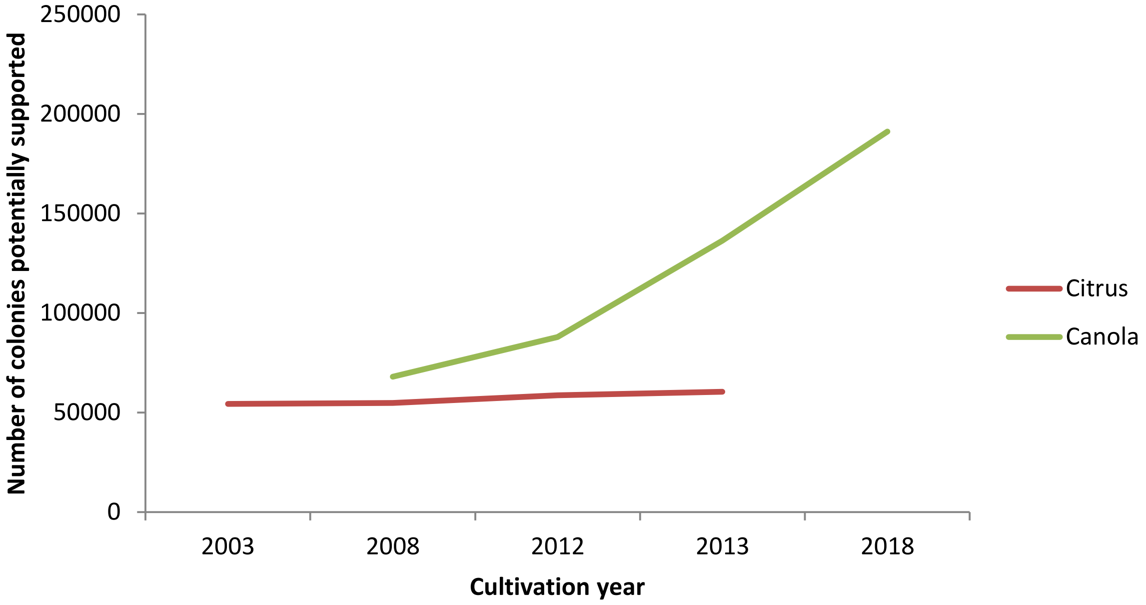

Figure 5.2: The number of colonies potentially supported by citrus and canola between 2003 and 2013, and predictions for canola in 2018.

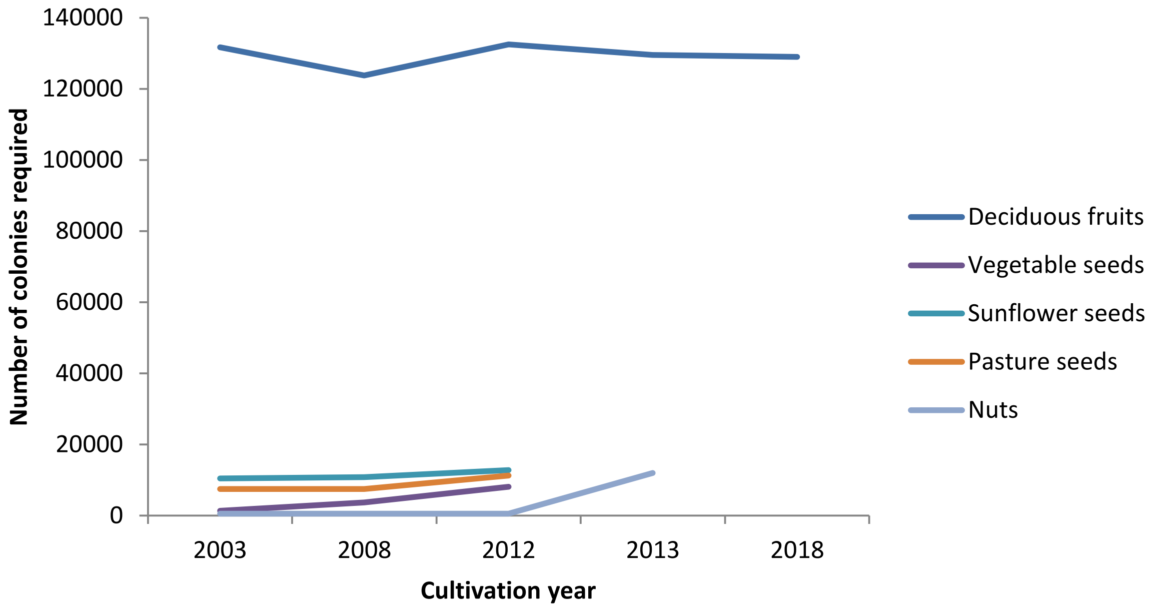

Figure 5.3: The number of managed honey bee colonies required for pollination of specific crop types between 2003 and 2013, as well as predictions for 2018 where available.

Table 5.1: Planting areas in hectares for various crops for the year 2003, 2008, 2012 and 2013 (plus projected hectares for 2018) with resulting pollination demand and forage supply in terms of the calculated number of managed honey bee colonies.

Crop plant		**Area planted (Ha)**					**[ƚ]Bee factor (%)**	**[ƫ]Hives/ha**	**Number of colonies**				
Scientific name	**Common name**	**2003**	**2008**	**2012**	**2013**	**2018**			**2003**	**2008**	**2012**	**2013**	**2018**
Malus domestica	Apple	21818	20731	22169	22499	22389	95	2	43636	41462	44338	44998	44778
Pyrus communis	Pear	13412	12691	13051	12033	11764	95	4	53648	50764	52204	48132	47056
Prunus americana	Apricot	4617	3748	3230	3020	3114	65	1	4617	3748	3230	3020	3114
Prunus persica	Nectarines	1393	1892	2137	2239	2230	65	1	1393	1892	2137	2239	2230
Prunus persica	Peach	1349	1377	1694	1770	1767	65	1	1349	1377	1694	1770	1767
Prunus domestica	Plum	4499	4081	4810	4895	4997	90	6	26994	24486	28860	29370	29982
Prunus avium	Cherry	66	197	227	225	-	90	2	132	394	454	450	-
Passiflora edulis	Granadilla	-	-	-	260	-	60	1	-	-	-	260	-
Persea americana	Avocado	-	-	-	4706	-	85	2	-	-	-	9412	-
Litchi chinensis	Litchi	-	-	-	441	-	85	2	-	-	-	882	-
Macadamia integrifolia	Macadamia	-	-	-	5749	-	75	2	-	-	-	11498	-
Magnifera indica	Mango	-	-	-	2994	-	85	3	-	-	-	8982	-
Prunus duicis	Almond	100	100	100	100	-	95	5	500	-	500	500	-
Allium cepa	Onion (seed)	129	5612	1450	-	-	95	5	645	-		**7250 -	-
Daucus carota	Carrot (seed)	142	171	175	-	-	?	5	710	855		**875 -	-
Helianthus	Sunflower	1740	1796	2126	-	-	95	6	10440	10776		**12756	-

annuus	(seed)											-	
Allium porrum	Leeks	-	26	46	-	-	50	6	-	156	276	-	-
Medicago sativa	Lucerne (hay seed)	1500	1472	2205	-	-	90	5	7500	7360	11025	-	-
Colony demand	**Total Ha**	50765	48844	53420	60931	46261		**Total colonies**	151564	146580	144718	182394	128927
**Citrus* spp	Citrus species	54322	54867	58580	60487	-	40-75	1	54322	54867	58580	60487	-
^*Brassica napus* var. *oleifera*	Canola	28400	34000	43980	68160	95600	65	2	-	68000	87960	136320	191200
Forage supply	**Total Ha**	82722	88867	102560	128647	95600		**Total colonies**	54322	122867	146540	196807	191200

* includes orange, mandarin, naartjie, lemon – Growers do not pay for pollination, but citrus is valuable pollination for beekeepers

^ Growers do not pay for pollination, but canola is valuable for forage and trapping of swarms

ⱡ Bee factor indicate improvement in yield with honey bee pollination. Values adopted from Johannsmeier & Mostert 2001.

Ŧ Minimum hives required per hectare given by growers and outlined in Johannsmeier & Mostert 2001

** Planting area data combined for 2012 & 2013 as supplied by the data provider.

Provincial crop pollination demands

Summary province comparisons for pollination services indicate the Western Cape to have the highest pollination demand throughout. In fact, the demand was steady between 2003 and 2008, with a sharp increase (<20%) in 2013 (Table 5.2). Pollination demands for the remaining eight provinces were below 10%. However, Eastern Cape had demands of over 5% during the 2003-2012 time periods. Limpopo was the only other province with a pollination demand over 5%, but only for 2013. The pollination demand for those areas not described above were 12% between 2003 and 2012. Canola and citrus are not shown in the table.

A breakdown of pollination demand in respective provinces is further broken down per crop category in Table 5.3. Few provinces have similar crop categories requiring pollination, although the demand is not the same. Deciduous fruits were common in eight of the nine provinces, with the exception of KwaZulu-Natal. The pollination demand was highest in the Western Cape (46.5%-63.2%), Northern Cape (11.2%-86.6%), Free State (81.6%-91%), Gauteng (8%-100) and North West (87.6%-89.4%) in comparison to other crop categories. However, each province experienced varied fluctuations between 2003 and 2013 (Table 5.3). Subtropical fruits had a pollination demand of less than 30% in four provinces of the five provinces planted, with Gauteng the only one with a demand of 34%. The pollination demand for nuts was high in Gauteng (58%) and KwaZulu-Natal (45.9%) for the year 2012. Cherry pollination was less than 1% for all provinces except the Free State (9-13%) between 2003 and 2013 and North West (11) for 2012. Cherries have subsequently been omitted from the Table 5.3. For the unidentified areas, sunflower and pasture seeds had steady pollination demands between 2003 and 2012, compared to vegetable seeds which had an increase from 7% to 24.3% during the same period.

Table 5.2: Summary of pollination demand across provinces.

Province	2003		2008		2012		2013	
	Total hives	%	Total hives	%	Total hives	%	Total hives	%
Western Cape	116572	76.9	106835	72.9	114578	58.4	127502	97.5
Mpumalanga	819	0.5	584	0.4	7247	3.7	628	0.5
Northern Cape	4339	2.9	5376	3.7	6528	3.3	178	0.1
Free State	443	0.3	1063	0.7	1112	0.6	1250	1.0
Eastern Cape	8963	5.9	9658	6.6	9769	5.0	134	0.1
Limpopo	640	0.4	781	0.5	15576	7.9	883	0.7
Gauteng	231	0.2	32	0.0	400	0.2	134	0.1
North West	254	0.2	286	0.2	126	0.1	0	0.0
KwaZulu-Natal	8	0.0	8	0.0	7585	3.9	30	0.0
Undescribed areas	19295	12.7	21947	15.0	33368	17.0	0	0.0
Total	**151564**		**146570**		**196289**		**130739**	

Table 5.3: Provincial pollination demand for different crop categories for the period 2003 to 2013.

Province	Crop category	2003		2008		2012		2013	
		Total hives	%	Total hives	%	Total hives	%	Total hives	%
Western Cape	Deciduous fruits	115990	63.2	106155	56.9	113830	53.9	126750	46.5
	Subtropical fruits	-	-	-	-	10	0.0	30	0.0
	Nuts	500	0.3	500	0.3	500	0.2	500	0.2
Mpumalanga	Deciduous fruits	817	6.7	574	5.1	582	4.1	484	5.0
	Subtropical fruits	-	-	-	-	3779	26.9	100	1.0
	Nuts	-	-	-	-	2882	20.5	--	0.0
Northern Cape	Deciduous fruits	4339	86.6	5376	88.7	6518	84.2	178	11.2
Free State	Deciduous fruits	403	91.0	867	81.6	1008	90.6	1086	86.9
Eastern Cape	Deciduous fruits	8963	38.5	9658	49.0	9645	43.1	134	1.0
	Subtropical fruits	-	-	-	-	58	0.3	-	-
	Nuts	-	-	-	-	66	0.3	-	-
Limpopo	Deciduous fruits	640	4.5	781	4.3	736	1.8	763	3.1
	Subtropical fruits	-	-	-	-	12232	29.6	100	0.4
	Nuts	-	-	-	-	2608	6.3	-	-
Gauteng	Deciduous fruits	231	100.0	32	100.0	32	8.0	134	100.0
	Subtropical fruits	-	-	-	-	136	34.0	-	-
	Nuts	-	-	-	-	232	58.0	-	-
North West	Deciduous fruits	254	87.6	286	89.4	112	88.9	-	-
KwaZulu-Natal	Subtropical fruits	-	-	-	-	2483	22.3	30	0.9
	Nuts	-	-	-	-	5102	45.9	-	0
Undescribed areas	Nuts	-	-	-	-	608	1.8	-	-
	Subtropical fruits	-	-	-	-	578	1.7	-	-
	Vegetable seeds	1355	7.0	3655	16.7	8125	24.3	-	-
	Sunflower	10440	54.1	10776	49.1	12756	38.2	-	-
	Pasture seeds	7500	38.9	7516	34.2	11301	33.9	-	-

5.3.3 Forage that managed honey bees depend on during pollination

Percentage contribution of forage categories and forage types

Exotic forage was primary forage for the eight provinces during pollination, supporting 80-100% of the colonies (Figure 5.4). It was only in the Eastern and Western Cape whereby indigenous forage provided some food for colonies during pollination. However, the number of colonies supported were minimal (>20%). The dominant forage type used during pollination was agricultural crops. More than 70% of the colonies in the eight provinces were dependant on agricultural crops for forage (Figure 5.5). It was only in the Eastern and Western Cape that colonies used other forage types besides agricultural crops. However, the forage sources accounted for a combined 14.1% and 30.4% in the Eastern and Western Cape respectively. Eucalyptus was only preferred for forage in the Western Cape, supporting 6.3% of the colonies.

Chi-square results show a statistically significant difference in the forage grouping between the nine provinces. In particular, Agricultural crops are of very significant ($p<0.001$) use in all nine provinces (Table 5.4). Although other forage categories in the Eastern Cape and Western Cape had some level of significance, these were of negative significance (Table 5.4).

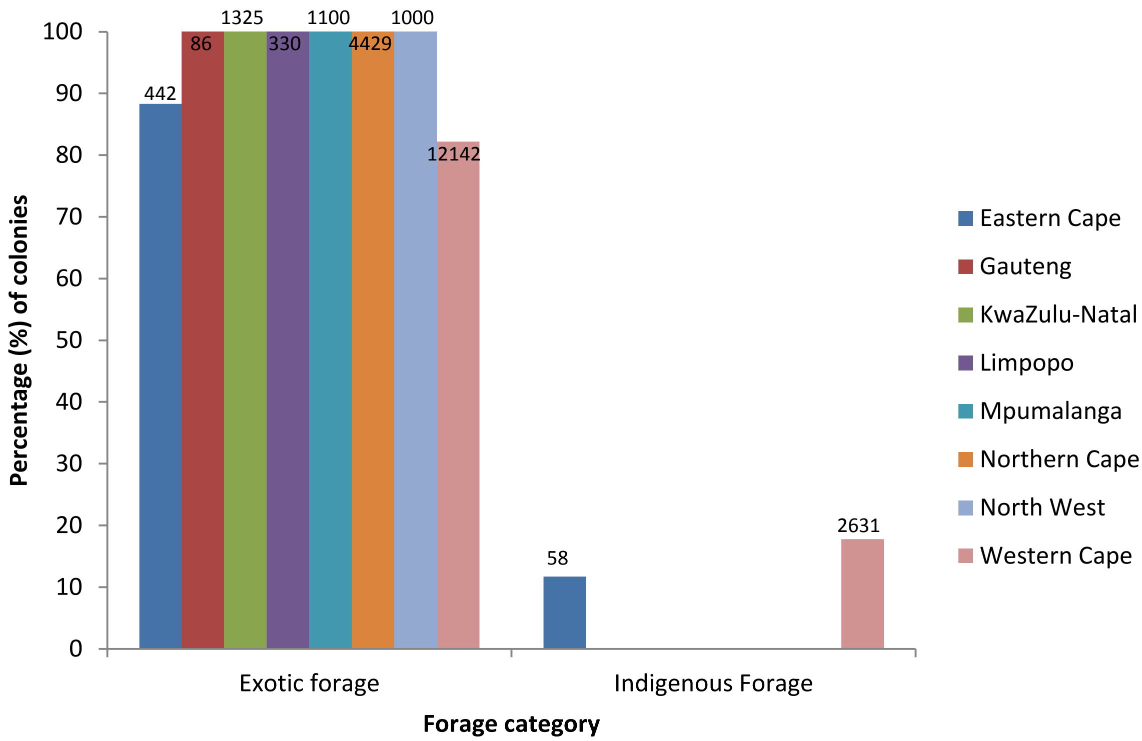

Figure 5.4: Percentage of colonies using different forage categories during pollination. The total number of colonies in a province maintained per forage category is indicated on top of each corresponding bar.

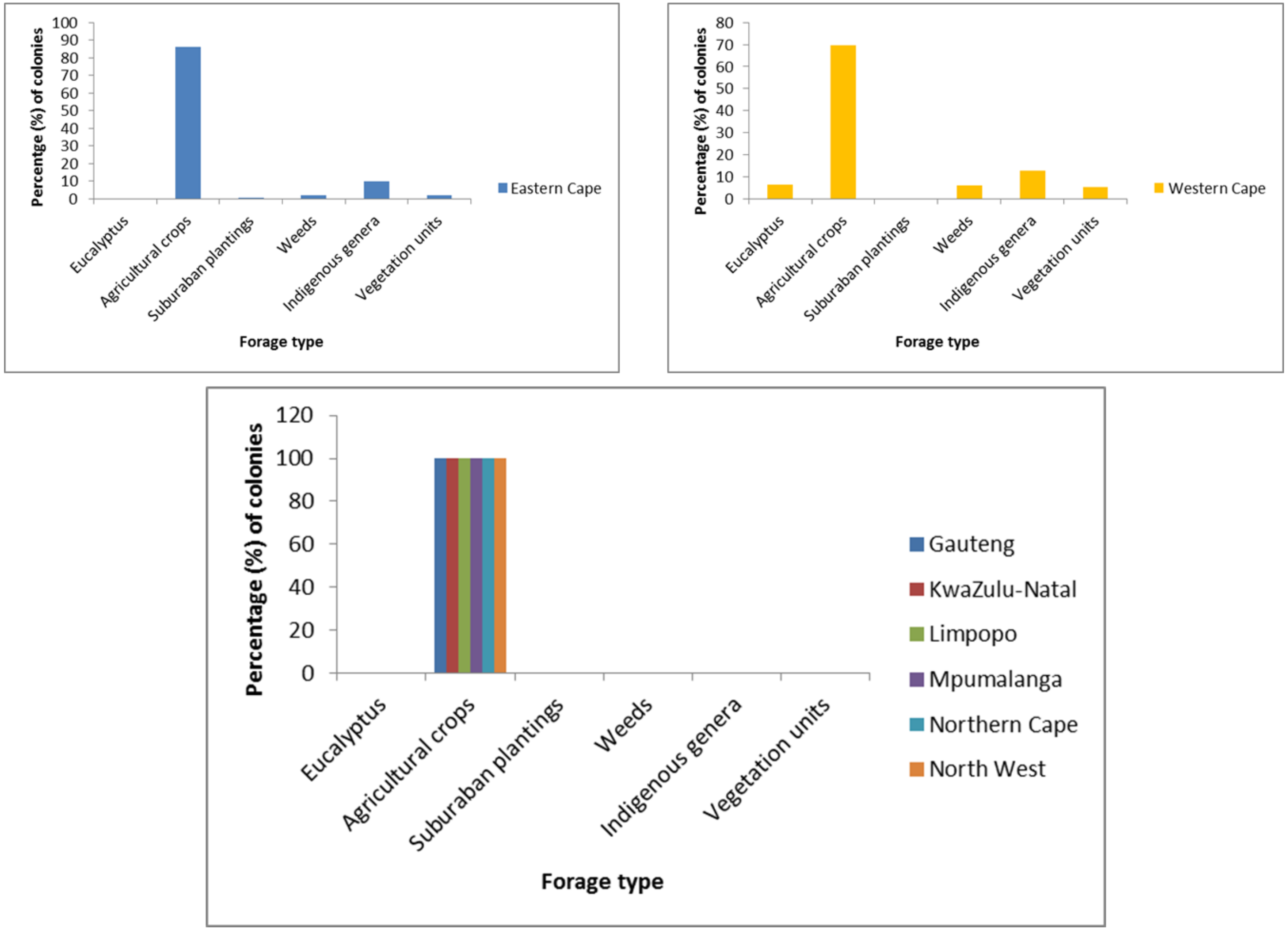

Figure 5.5: Percentage of colonies using different forage types during pollination in each province.

Table 5.4: Forage type frequency variability for the different provinces. The relationship among the forage types is indicated by X^2 and the level of significance by P (p-value, denote by the significance at P < 0.05, 0.01 and 0.001 respectively) and the level of no significance (ns) denoted by α = 0.05.

Province	Eucalyptus		Agricultural crops		Suburban plantings		Weeds		Indigenous genera		Vegetation units	
	X^2	P	X^2	P	X^2	P	X^2	P	X^2	P	X^2	P
EC	16.7(-)	<0.01	288.4(+)	<0.001	16.7(-)	<0.01	12.9(-)	<0.05	2.7(-)	ns	12.9(-)	<0.05
FS	16.7(-)	<0.01	416.7(+)	<0.001	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01
GP	16.7(+)	<0.01	416.7(+)	<0.001	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01
KZN	16.7(-)	<0.01	416.7(+)	<0.001	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01
L	16.7(-)	<0.01	416.7(+)	<0.001	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01
MP	16.7(-)	<0.01	416.7(+))	<0.001	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01
NC	16.7(-)	<0.01	416.7(+)	<0.001	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01
NW	16.7(-)	<0.01	416.7(+)	<0.001	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01
WC	6.8(-)	ns	170.7(+)	<0.001	16.7(-)	<0.01	6.8(-)	ns	0.8(-)	ns	8.2(-)	ns

() parenthesis indicates whether the significant level of the relationship slope was positive (+) or negative (-).

Significant forage sources within South Africa

Major forage sources for colonies during pollination were in most provinces restricted to agricultural crops. The Eastern and Western Cape were the only two provinces not to have forage sources limited to agricultural crops. In the Eastern Cape and Mpumalanga Province, avocado (*Persea americana*) was important for supporting 79.9% and 29.1% of the colonies during pollination. Macadamia supported majority of the colonies in four different provinces. It was first preference forage in the North West Province, supporting 95% of the colonies, and second preferred forage in KwaZulu-Natal, Limpopo and Mpumalanga supporting between 15-27% colonies (Table 5.5).

In Gauteng, KwaZulu-Natal and Northern Cape, sunflower (*Helianthus annuus*) was the most important forage for colonies during pollination. Here, sunflower supported between 60-83% colonies (Table 5.5). Curcubita was the most important forage source in Limpopo, supporting 78.8% of the colonies. In contrast, curcubita supported >10% of the pollination colonies in the Northern Cape and the North West Province (Table 5.5).For the Western Cape, pollination forage use was strongly diverse. Canola (*Brassica napus* var. *oleifera*) and apple (*Malus domestica*), were the major forage source. They each supported 25.6% and 20.1% colonies respectively. Other forage sources (combined) were responsible for less than 8% colonies each (Table 5.5).

Table 5.5: Forage sources supporting more than 5% of the colonies in respective provinces during pollination.

Province	Forage source	Common name	% colonies supported
Eastern Cape (501)	*Persea americana*	Avocado	79.9
	*Other forage sources		20.1
Gauteng (86)	*Helianthus annuus*	Sunflower	71.9
	Passiflora edulis	Granadilla	15.
	Rubus idaeus	Raspberry	9.3
	*Other forage sources		3.1
KwaZulu-Natal (1325)	*Helianthus annuus*	Sunflower	83
	Macadamia spp.	Macadamia	15.3
	*Other forage sources		1.7
Limpopo (330)	*Macadamia* spp.	Macadamia	21.2
	Curcubita spp.	Curcubita	78.8
Mpumalanga (1100)	*Persea americana*	Avocado	29.1
	Macadamia spp.	Macadamia	27.3
	Malus domestica	Apple	21.8
	Rubus idaeus	Raspberry	16.4
	Phaseolus vulgaris	Kidney beans	5.5
Northern Cape (4229)	*Madicago sativa*	Lucerne	5
	Allium cepa	Onion	25.5
	Helianthus annuus	Sunflower	60.5
	Cucurbita spp.	Curcubita	8.5
North West (1000)	*Macadamia* spp.	Macadamia	95
	Cucurbita spp.	Curcubita	5
Western Cape (14772)	*Eucalyptus cladocalyx*	Sugar gum	6.2
	Mountain Fynbos		7.9
	Brassica napus var. *oleifera*	Canola	25.6
	Malua domestica	Apple	20.1
	Madicago sativa	Lucerne	6.3
	Prunus spp.	Prune/Plum	5
	*Other forage sources		29.0

() Number in brackets indicates the total number of hives used for pollination for each province.

* Percentage total of other forage source that does not support more than 5% of colonies individually in the province or might not be of use for honey crop in the province (see Appendix C for full listing)

5.3.4 Number of localities used by colonies during pollination

Colony numbers differed provincially and per listed localities. The Western Cape Province had the most number of areas listed (59), compared to the other eight provinces that had less than 10 areas each. In the Easter Cape, Baviaanskloof and Port Alfred were the only two areas indicated to support the province's 501 colonies during pollination. They supported 20.1% and 79.9% colonies respectively. For Gauteng, the seven listed areas supported a total of 86 colonies. Nigel and Villiers supported 34.9% colonies each, while Bela Bela (located in Limpopo) supported 20.9% colonies, with the other remaining four areas supporting a combined 9.3% of the colonies. Port Shepstone, Margate, Winburg (located in Free State) and Bethlehem (located in Free State) were the only four areas listed to support KwaZulu-Natal's 1345 pollination colonies. Winburg accounted for majority of the colonies (800, 60.4%) compared to Bethlehem (300, 22.6%). Port Shepstone and Margate each supported 8.5% colonies. Here, it's important to note the colony migration from Gauteng and KwaZulu-Natal into other provinces.

Makhado in Limpopo Provinces was the only area given to support the provinces' 300 colonies during the pollination period. In Mpumalanga, only two areas were listed, supporting the province's 1100 colonies. White River supported 800 (72.7%) and Ermelo 300 (27.3%) colonies. For the Northern Cape, Douglas was the only area supporting entire 4229 colonies during pollination. The North West Province had a total of 1000 colonies used for pollination, of which 95% were placed in Litchenburg and only 5% was placed in Vryburg. In the Western Cape, a total of 14772 colonies were placed in 59 different localities across the province. Of the 59 areas, four (Ceres, Grabouw, Stanford and Albertinia) supported more than 5% (>730) colonies each, while eight areas supported between 3-5% (440-730) and the remaining 47 areas supported less than 3% each (<440). Localities that maintained more than 550 colonies could be found in the Free State, Mpumalanga, Northern Cape, North West and Western Cape (Figure 5.5). Refer to Appendix H for all pollination colonies kept per specific locality in respective provinces.

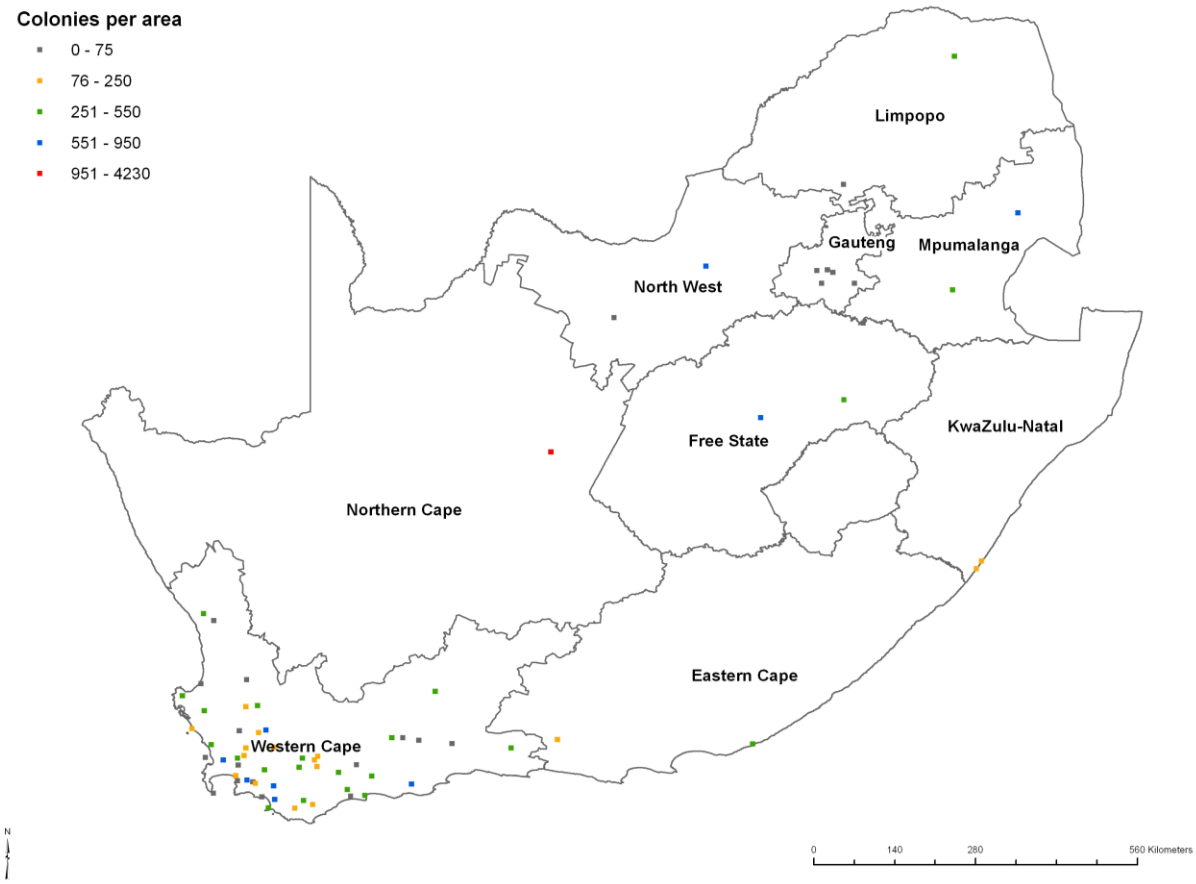

Figure 5.4: Localities in South Africa where forage is accessed during pollination (as disclosed by beekeepers to nearest town). The colour of locality point indicates the range of colonies supported per locality

5.4 Discussion

5.4.1 Use of managed honey bees for crop pollination

The pollination of cultivated crops is one of the most important services provided by beekeepers (Clark 2012). The scale and intensity at which beekeepers rent out their colonies for pollination services differs according to the priorities of beekeeping practices. It therefore makes sense that beekeepers will not rent out their entire colony stock for pollination season seasonally. In both surveys, it is evident that beekeepers partition their beekeeping stocks to pollination and other productions (i.e. honey). Also, it does not mean that if beekeepers manage a large stock, they would automatically rent out a huge portion of those for pollination. This assumption is drawn from the pollination hives outlined in both surveys. For example, in both surveys the Eastern Cape, Gauteng, KwaZulu-Natal and Limpopo Province recorded low use of colonies for crop pollination despite having higher colony numbers. Alternatively, it could be that there is no demand for more hives for pollination in these provinces. Also, another interesting observation is that of the Western Cape Province. Responses from the forage survey showed that only 60% of hives were used for pollination. This is regarded as a low percentage given that the province generally has a high demand for crop pollination (Allsopp & Cherry 2004; Allsopp et al. 2008). There are three possible reasons for this: 1) that beekeepers gave incorrect number of hives they use for pollination; 2) that those beekeepers who responded to the questionnaire provide minimal pollination services; and 3) at times beekeepers also use the crops they provide pollination services for as honey crop and might not want growers knowing this as it might reduce the pollination fee been paid for – but this is subjected to debate as hives used for honey production are often not used to render pollination services.

The forage use survey highlighted various crops that beekeepers render pollination services for in respective provinces. The variability in pollination hives used for different crops was not surprising as beekeepers render pollination for different reasons. It can be for honey crop, in instances were no charge is involved, and other beekeepers always opt for charge based pollination contracts (Morse & Calderone 2000). At the same time, farmers would not pay for rental hives if they believed that the hives do not add value to their production (Aebi *et al*. 2012). According to Clark (2012), the biggest pollination contracts are for sunflower seed (i.e. Klein Karoo and Northern Cape) production and the fruit industry in the Western Cape. This is concurrent with the study findings as a high percentage of colonies in Gauteng, KwaZulu-Natal, Northern Cape and the North West were used for oil seeds pollination. Similarly, the fruit industry in the Western Cape utilized 81.5% (<12000 hives) for pollination annually. This was relatively a small number compared to the findings of Allsopp & Cherry (2004), Allsopp *et al*. (2008) and de Lange *et al*. (2013). In these studies, pollination hives for the fruit industry in the Western Cape were estimated to be above 30000.

Pollination information on most vegetables and vegetable seeds has proved difficult in most areas globally, including the USA (Morse & Calderone 2000). Here we witness the small colony percentage dedicated to these crops for pollination. The low yields in both nectar and pollen from these crops often deter beekeepers in offering pollination services especially when farmers are not willing to pay fees (Clark 2012). The use of commercial honey bees for melon pollination is common although not for all cultivars (Stanghellini *et al*. 1998; Morse & Calderone 2000). The use of commercial hives for melon pollination in Limpopo and the Northern Cape highlights the importance of rented hives to render the pollination services in these areas. Majority of the subtropical fruits (i.e. avocado, mangoes and kiwi fruits), do require cross pollination and this is largely carried out by insects (Morse & Calderone 2000). The results here indicate a substantial amount of managed honey bees to be used in rendering pollination services in subtropical fruits, particularly in the Eastern Cape, Limpopo and Mpumalanga. Therefore, managed honey bee contribution to most crops is important and requires good recognition (Kremen *et al*. 2002).

5.4.2 Crop planting area and crop pollination demand

Crop planting

Food security is high on the global agenda together with other agricultural products. The demand in these products increases with the increase in populations, resulting in increased practices relating to agricultural intensification (Garnett *et al*. 2013). Consumer market trends and preferences also drive the supply and demand of various agricultural crops (DeFries *et al*. 2010; Tilman *et al*. 2011). Although not all such crops require insect pollination, there are concerns over increases in various agricultural production areas as they are likely to suffer pollination shortages (Aizen & Harder 2009). At the same time, studies by Ellis *et al*. (2015) and Chaplin-Kramer *et al.* (2014) attempt to link the contribution of pollinators to human nutrition. Although both studies acknowledge the complex nature of the links, they successfully show that individuals who receive the majority of their nutrients from fruits and vegetables that depend heavily on pollinators are likely to be the most affected in the loss of pollinators. Therefore, global concerns over pollinator shortages in the agricultural industry should be taken seriously (Delaplane & Mayer 2000; Kremen & Ricketts 2000; Holden 2006).

South Africa, unlike Europe and the USA has no reliable data for most crops and pollination supply versus demand. The variability in different stocking rates for different crops means that estimations for pollination demands are not always easy to determine (Breeze *et al*. 2014). This study is the first to attempt a correlation of various crops planting with their pollination requirements. In the data available for various crops across respective years, pollination demand increases with the increase in planting area. The decrease thereof was vice versa. Deciduous fruits such as apples, plums, pears and apricots that are known to be dependent on managed honey bee pollination (see Allsopp *et al*. 2008) were indicated to require between 3000-45000 colonies annually (see Table 5.1). For crops such as apples, pears and plums colonies estimated here for respective years are exceed the number of colonies captured by the survey used for this study. However, this supports Allsopp & Cherry (2004), Allsopp *et al*. (2008) and de Lange *et al*. (2013) who postulated that most deciduous crops of the Western Cape require more than 30000 colonies for pollination annually.

For crops such as citrus and canola, which most cultivars do not require insect pollination (Johannsmeier 2001), the study showed their importance (present and future) in providing forage for colonies. They have the potential to support an extra 4000 colonies than those captured by my survey. With the planting projection for canola indicating a massive increase, the potential to support more colonies is possible (see Table 5.1). Although Pirk *et al*. (2014), estimates a 100000 colonies for South Africa, this has never been varied.

Data gathered for subtropical fruits only represented one planting season and was therefore not sufficient to can draw comparison and conclusions for any increase or decreases in planting areas, and therefore pollination demands. However, crops such as avocado, mango and macadamia require insect pollination (Morse & Calderone 2000) and make use of managed honey bees in South Africa (Johannsmeier 2001), therefore any increase in planting area will result in an increase in pollination demand. Onion, carrot, sunflower and lucerne had reliable seasonal data complemented by managed honey bee stocking rates. The increase in production across the five year intervals also saw an increase in managed honey bee colonies. The current rate of annual increases in plantings means that pollination demands are likely to be met although fears of pollination shortage are already looming for these crops (Mike Allsopp & John Moodie pers. comm. 2014). It is said that since 2012, there has been a pollination shortfall of roughly 15000 hives annually for onion pollination in the Klein Karroo region of the Western Cape. There are fears that the shortage will only worsen in years to come if the matter is not given adequate attention.

Although the increased demand of managed honey bees for crop pollination is clear for most crops, the lack of understanding in the trends and drivers of planting increases together with readily available reliable data makes it difficult to fully justify importance in the rise of pollination services. Breeze *et al*. (2014) allude that understand these trends are crucial in the planning and monitoring pollination services. It makes it easier to quickly identify and attend to any gaps as a result of inadequate pollination. Furthermore, the summary on hive demands for pollination of various crops (grouped into categories) provided in Figure 5.3, showed that pollination demand is likely to decrease or increase with planting area. And that crop currently stable in cultivation land are likely to remain as such, and so is their demand for pollination. Here, deciduous fruits, citrus and vegetable seeds were good examples to this observation and trend.

Provincial pollination demands

Agriculture is to a large extent dependent on climatic conditions (Gregory & Ingram 2000). Climate is important in determining potential agricultural activities and suitability (Lin *et al*. 2008). South Africa's agricultural practices occur across a wide variety of climatic conditions (especially of rainfall). Roughly 90% of the country is sub-arid, semi-arid, or sub-humid, and about 10% is considered hyper-arid. Only 14% of the country is potentially arable, with one fifth of this land having high agricultural potential (Munzhedzi & Motsepe 2013). Different crops and cultivars are also only suitable for certain areas given their environmental requirements. Moreover, it is for such reasons that various crops (grouped into categories) outlined in Table 5.2 tend to vary among provinces. Some crops start off well in certain areas across the country before collapsing. Some good examples from this study include nectarines and plums in Gauteng, cherries in KwaZulu-Natal and citrus in North West. At the same time, other crops can experience large fluctuations in planting area over time (see Table 5.1). This is an indication that as climatic conditions change, become suitable, some crops will be more favoured than others. Also, the change in market trends and consumer demands cannot be ignored (Breeze *et al*. 2014). It for this reason that variation in pollination demands was observed across provinces (see Table 5.3) and crop categories for the stipulated period.

The Western Cape remained the highest in terms of pollination demand for the outlined time line. This was largely attributed to deciduous fruits. An earlier study by Allsopp *et al*. (2008) also indicates deciduous fruit growers in the Western Cape to be largely dependent on managed honey bees for pollination. However, the high demand for pollination of deciduous fruits was not unique to the Western Cape. Provinces such as the Free Sate, Eastern and Northern Cape also had high, but variable pollination demands (percentage) – an indication that deciduous fruits are generally dependent on honey bee pollination (Allsopp *et al*. 2008; Melin *et al*. 2014). This means that if more areas become suitable for deciduous fruits across the country, the pollination demand will increase drastically needing more bees to provide the service.

5.4.3 Forage that managed honey bees depend on during pollination

<u>Percentage contribution of forage categories and forage types pollination</u>

Forage preference during pollination is vaguely documented as honey bees are generally considered to forage on what they can access within the landscape (Gathmann & Tscharntke 2002). In farming landscapes, this often means that cultivated crops are often the only forage available therefore compromising the variety of nutrition essential for bee health (Alaux *et al*. 2010; Levy 2011). Results indicate agricultural crops to be the major forage during pollination in all provinces. This supports the tested hypotheses. Other forage types (i.e. weeds, eucalyptus, vegetation units) in the Eastern and Western Cape supported small amount of pollination hives. This is typical for landscapes have become increasingly characterized by agriculturally intensive monocultures as a result of human-defined ecosystems (Naug 2009). In such instances whereby 80-100% of colonies are solemnly dependant son agricultural crops for forage during pollination, it is important that beekeepers ensure they go into pollination well build up (Johannsmeier 2001) or that supplementary feeding is provided throughout the pollination period (Schmidt *et al*. 1995).

Eucalyptus featured only in the Western Cape as an important forage source for colonies during pollination. Although it accounted for a low percentage of colonies (<6.2%), several eucalyptus species have previously been documented to be good forage during and after the pollination season in the Western Cape (see Allsopp & Cherry 2004; de Lange *et al*.

2013). According to Johannsmeier & Mostert (2001), eucalyptus provides relief forage at a critical time of the year when most of the indigenous forage is not in flower (Johannsmeier 2001).

Significant forage sources within South Africa

Honey bee diet is supported by a diverse mixture of pollen from many different plant species (Dimou & Thrasyvoulou 2009). However, in agricultural landscapes, there is often less diversified diet and this may not fully provide for all the nutritional needs. Also not all agricultural crops have high crude protein content and reasonable nectar flows for adequate colony nourishment. This study found Gauteng, Mpumalanga, Northern Cape and Western to be the only provinces with a wide variety of forage that support colonies during pollination. For example, the Western Cape had 31 different forage sources used by colonies during pollination compared to only two species in Limpopo and Northwest respectively. Therefore, honey bees in provinces with limited forage species to forage on during pollination have less choice of nectar and pollen. As a result they stand a higher risk of malnutrition, starvation and possibly death (Alaux *et al*. 2010).

Crops such as canola (Johannsmeier & Mostert 2001; Pirk *et al*. 2014), sunflower (Nicolson & Human 2012), sweet clover (Campana & Moeller 1977) and mustard (Singh & Singh 1996) are considered to be some of the best forage for bees based on their pollen content. Here, sunflower is valuable forage for pollination colonies in Gauteng, KwaZulu-Natal and the Northern Cape. This is because sunflower provides sufficient nutritious pollen on which honey bees build up their strength (Johannsmeier & Mostert 2001). Similarly, as shown is previous studies (see Johannsmeier & Mostert 2001; Allsopp & Cherry 2004) and now this study, canola is valuable forage in the Western Cape as it stimulates an increase in brood production and is ideal for colonies to build-up their strength in preparation for the pollination season.

Honey bees are generally the most abundant and active insects foraging on macadamia (Gary *et al*. 1972). Although there is strong evidence that indicate certain macadamia varieties to benefit significantly from honey bee pollination (Shigeura 1967; Shigeura *et al*. 1970), the pollen and nectar content is too low to ensure adequate bee nutrition

(Johannsmeier & Mostert 2001). In this study, macadamia was found to be the most used forage source in four provinces during pollination. For the North West in particular, macadamia supported 950 (95%) of the colonies during pollination. Even with the low pollen and nectar content, bees find themselves forced to forage on macadamia most likely because it is the only forage available at the time. This is mostly the case with large commercial farms that plant monoculture resulting in no alternative forage and colonies are only subjected to one source of forage throughout the pollination period (Levy 2011). For agricultural fields adjacent to natural vegetation, avocado is visited by a diversity of insect species that perform efficient pollination (Ish-Am *et al*. 1999). In the absence natural areas and therefor native pollinators, honey bees are used successfully and almost exclusively for avocado pollination (Ish-Am & Eisikowitch 1993; Ish-Am *et al*. 1999). This explains the high number of hives used for avocado pollination in the Eastern Cape and Mpumalanga Province. At the same time, avocado serves as the primary forage source for these colonies throughout the pollination season. The qualitative nectar content score for avocado is slightly higher than the pollen value for this crop (Johannsmeier & Mostert 2001).

Citrus pollination by honey bees is debatable given the variability in various cultivars and their characteristics (Sanford 2010). However, its high value for nectar content enables the production of good quality honey (Johannsmeier & Mostert 2001; Sanford 2010). Citrus is historically known to be good forage during the winter periods in most South African provinces (Hutton-Squire 2014), and it is not surprising to see it documented here as an important forage source during pollination. Curcubita spp., apple, onion and kidney beans, which are regarded as small honey crops are also shown here to support colonies during pollination. Cucurbita spp. in particular, was an important forage source for pollination colonies in Limpopo. In essence, the use of forage sources tends to be determined by their availability and accessibility rather than them being generally favoured by beekeepers.

5.4.4 Number of localities used by colonies during pollination

Annually, beekeepers travel long distances to provide pollination services for various crops because bee hives within the vicinity (if any) are unable to meet the demand (see Morse & Calderone 2000; Delaney & Tarpy 2008). Similarly, the lack of good forage resources makes it difficult for migratory beekeepers to find suitable, accessible forage sites to keep their bees (Benjamin & McCallum 2008). For this study in particular, localities listed for forage use during pollination were assumed to be the same as those were pollination services were rendered. In addition, cross boarder migrations were not only evident for provinces such as Gauteng and KwaZulu-Natal, but these areas supported substantial amount of colonies (<20%). As much of importance as it is a forage issue, the pollination demand in respective areas dictates the movement of hives during this period (Clark 2012), At times, the crop types are also taken into account given the pesticide issues associated with most crops (Johannsmeier 2001). The fact that some provinces had a lower number of localities used for forage during pollination compared to others also suggests that those were the only areas with active pollination at the time. At the same time, the various stocking rates across localities resemble the likely proportion in pollination demand for different crops at a given time. In fact, different crops have different stocking rates due to their pollination requirements (Breeze *et al*. 2014). Therefore, it was not surprising that my results here outlined this trend.

5.5 Conclusion

Surveys have been used in many studies globally to record or capture hive numbers across beekeeping operations. Although these surveys are often inconsistent or biased in the data gathered, they are seldom the only way to obtaining such data (see Chapter 2). The use of two independent surveys in this study highlighted the inconsistencies in reporting and general diversity in response from beekeepers. In addition, valuable data on pollination trends across the province pointed out key pollination activities in different provinces. We can now identify discrepancies between colonies numbers used for pollination in each province and what crops they pollinate versus what the demand over time is. The Western Cape remains the province with high pollination activity in both surveys, with Free State having little to no records. Oil seeds, deciduous, subtropical and nuts had high pollination demands compared to other crops.

Understanding the planting dynamics of various crops proved challenging given the gaps in the data provided. Other crops had only a single years' planting data available. This made it difficult to draw comparison from year intervals and to assess the pollination demand. The fact that pollination data (hives used by growers and/or stocking density) was given for only four crops (all vegetable and pasture seeds and others adopted relevant from literature) meant that recommended stocking rates for pollination could only be used for these respective crops. At a national and regional level the pollination demand was found to be stable and to increase in accordance with an increase in production area. This makes sense since the planting area determines the amount of pollination required. However, the gaps or lack in production area data and pollination requirements suggests that no proper predictions or planning can be outlined correctly in this regard. A few studies have already highlighted the need for good reliable data when it comes to pollination demands and supply (Allsopp *et al*. 2008; vanEngelsdorp & Meixner 2010; Breeze *et al*. 2014), in order to avoid exaggerations and assumptions on pollinator deficits or even sounding alarms on the pollination crisis. Given the current data, it is without doubt that the pollination demand is bound to increase into the 2018 production year, particularly for most deciduous fruits, macadamia and vegetable seeds (i.e. onion and sunflower). Therefore, good reliable data is essential in both planting and pollination data to fully (and specifically) understand the pollination requirements for various crops dependant on the service.

Bee forage during pollination was largely dominated by exotics, agricultural crops in particular. The Eastern and Western Cape were the only two provinces to have a mixture of indigenous forage use during pollination. This not only brings to attention the lack of diversified foraging areas around agricultural fields, but also highlights the direct consequences of pollinating commercial crops. Further raising concerns about the quality nutrition the hives used for pollination receive. It is therefore important that bees come into pollination at good or full strength in order to compensate for the poor nutrition for the pollination duration, and this stems back to forage sources used weeks or months before pollination (see Chapter 6). Like with most beekeeping practices (i.e. honey crop and swarm trapping), the migration of beekeepers within and outside their provincial boarders was observed in the findings and given by locality names (see Chapter 2). In this instance, migrations are triggered by the rendering of pollination services rather than the primary search of good forage sites (see Chapter 3). Therefore, the amount of hives present in one area at a given time is also dictated by the pollination service required in the area. Complete and accurate census data on crop pollination services provided by beekeepers and the number of hectares for all crops requiring pollination is thus urgently required for proper planning to avoid pollination supply and demand shortfalls.

5.6 References

Aebi, A., Vaissière, B.E., vanEngelsdorp, D., Delaplane, K.S., Roubik, D.W. and Neumann, P. 2012. Back to the future: *Apis* versus non-*Apis* pollination. *Trends Ecology and Evolution* 27(3): 142-143.

Aizen, M.A., Garibaldi, L.A., Cunningham, S.A. and Klein, A.M. 2008. Long-term global trends in crop yield and production reveal no current pollination shortage but increasing pollinator dependency. *Current Biology* 18: 1572-1575.

Aizen, M.A. and Harder, L.D. 2009. The global stock of domesticated honey bees is growing slower than agricultural demand for pollination. *Current Biology* 19: 915-918.

Aizen, M.A., Garibaldi, L.A., Cunningham, S.A. and Klein, A.M. 2009. How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. *Annals of Botany* 103: 1579-1588.

Alaux, C., Ducloz, F., Crauser, D. and Le Conte, Y. 2010. Diet effects on honey bee immunocompetence. *Biology Letters* 6:562-565.

Allsopp, M.H. and Cherry, M. 2004. An assessment of the impact on the Bee and Agricultural industries in the Western Cape of the clearing of certain Eucalyptus species using questionnaire survey data. Pretoria (South Africa): National Government of the Republic of South Africa, Department of Water Affairs, Internal Final Report.

Allsopp, M.H., de Lange, W.J. and Veldtman, R. 2008. Valuing Insect Pollination Services with Cost of Replacement. *PLoS ONE* 3(9): e3128. doi:10.1371/journal.pone.0003128.

Benjamin, A. and McCallum, B. 2008. A world without bees. Canadian books, London, UK.

Brand, M.R. 2014. Pollination ecosystem services to onion hybrid seed crops in South Africa. PhD Thesis, University of Stellenbosch, Stellenbosch.

Breeze, T., Vaissière, B.E., Bommarco, R., Petanidou, T., Seraphides, N., Kozák, L., et al. Agricultural policies exacerbate honey bee pollination service supply-demand mismatches across Europe. *PLoS One* 9(1): e82996. doi:10.1371/journal.pone.0082996

Calderone, N.W. 2012. Insect pollinated crops, insect pollinators and US agriculture: Trend analysis of aggregate data for the period 1992-2009. *PLos ONE* 7(5): e37235. doi: 10.1371/journal.pone.0037235.

Campana, B.J. and Moeller, F.E. 1977. Honey bees: preference for and nutritive value of pollen from five plant sources. *Journal of Economic Entomology* 70: 39-41.

Cane J.H. 1997. Ground-nesting bees: the neglected pollinator resource for agriculture. *Acta Horticulturae* 437: 3-9

Carvalheiro, L. G., Seymour, C. L., Veldtman, R., Nicolson, S. W. 2010. Pollination services decline with distance from natural habitat even in biodiversity-rich areas. *Journal of Applied Ecology* 47: 810-820.

Chaplin-Kramer, R., Dombeck, E., Gerber, J., Knuth, K.A., Mueller, N.D., Mueller, M., Ziv, G. and Klein, A-M. 2014. Global malnutrition overlaps with pollinator-dependent micronutrient production. *Proceedings for the Royal Society B* 281: 20141799.

Clark, P. 2012. Tales of an African beekeeper: reflections on bees and beekeeping. Charleston, SC. USA.

DAFF, 2013. Retrieved: 26 January 2015: Retrieved from: http://www.daff.gov.za/daffweb3/Branches/Economic-Development-Trade-Marketing/Marketing/Annual-Publications.

DeFries, R.S., Rudel, T., Uriarte, M. and Hansen, M. 2010. Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience* 3: 178-181.

de Lange, W.J., Veldtman, R. and Allsopp, M.H. 2013. Valuation of pollinator forage services provided by *Eucalyptus cladocalyx*. *Journal of Environmental Management* 125: 12-18.

Delaney, D.A. and Tarpy, D.R. 2008. The role of honey bees in apple pollination. Beekeeping Note 3.03. Apicultural Program Department of Entomology North Carolina State University.

Delaplane, K.S. and Mayer, D.F. 2000. Crop pollination by bees. New York: CABI Publishing.

Dimou M. and Thrasyvoulou, A. 2009. Pollen analysis of honey bee rectum as a method to record the bee pollen flora of an area. *Apidologie* 40: 124-133.

Ellis, A.M., Myers, S.S. and Ricketts, T.H. 2015. Do Pollinators Contribute to Nutritional Health? *PLoS ONE* 10(1): e114805. doi:10.1371/journal.pone.0114805

FAO. 2009. Non-Wood Forest Products 19. Bees and their role in forest livelihoods: A guide to the services provided by bees and the sustainable harvesting, processing and marketing of their products. Food and Agricultural Organization of the United Nations (FAO), Rome, Italy.

Gallai, N., Salles, J.M., Settele, J., and Vaissicre, B.E. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics* 68: 810-821.

Garibaldi, L.A., Steffan-Dewenter, I., Winfree, R., Aizen, M.A., Bommarco, R., Cunningham, S.A., et al. 2013. Wild pollinators enhance fruit set of crops regardless of honey-bee abundance. *Science* 339 (6127): 1608-1611. DOI: 10.1126/science.1230200.

Garnett, T., Appleby, M.C, Balmford, A, Bateman, I.J, Benton, T.G, Bloomer, P., Burlingame, B., Dawkins, M., Dolan, L., Fraser, D. Herrero, M., Hoffmann, I., Smith, P., Thornton, P.K., Toulmin, C., Vermeulen, S.J., and Godfray1, H.C.J. 2013. Sustainable Intensification in Agriculture: *Premises and Policies. Science* 341 (6141): 33-34

Gary, N. E., Mau, R. F. L. and Mitchell, W. C. 1972. Preliminary study of honey bee foraging range in macadamia (macadamia-integrifolia, maiden and betche). *Proceedings of the Hawaiian Entomological Society* 21: 205-212.

Gathmann, A. and Tscharntke, T. 2002. Foraging ranges of solitary bees. *Journal of Animal Ecology* 71: 757-764.

Ghazoul, J. 2005. Buzziness as usual? Questioning the global pollination crisis. *TRENDS in Ecology and Evolution* 20: 367-373.

Gregory, P.J. and Ingram, J.S.I. 2000. Global change and food and forest production: future scientific challenges. *Agriculture Ecosystems and Environment* 82: 3-14.

Hardy, M. 2007. Crop rotation for rain-fed crop production. *AgriPROBE* 4(4): 9-17.

Holden C. 2006. Report warns of looming pollination crisis in North America. *Science* 314 (5798): 397.

Hutton-Squire, J.P. 2014. Historical Relationship of the Honey bee (Apis mellifera) and its forage; and the current state of Beekeeping within South Africa. MSc Dissertation, University of Stellenbosch, Stellenbosch.

Ish-Am, G., Barrientos-Priego, A.F., daVildozola, C.A. and Gazit S. 1999. Avocado (*Persea americana* Mill.) pollinators in its region of origin. *Revista Chapingo Serie horticultura* 5: 137–143.

Ish-Am, G. and Eisikowitch, D. 1993. The behavior of honey bees (*Apis mellifera*) visiting avocado (*Persea americana*) flowers and their contribution to its pollination. *Journal of Apicultural Research* 32: 175-186.

Johannsmeier, M.F. 2001. Beekeeping in South Africa. Plant Protection Handbook No. 14, Agricultural Research Council, Pretoria.

Johannsmeier, M. F. and Mostert, A. J. N. 2001. South African nectar and pollen flora. In: Beekeeping in South Africa, 3rd edition. Plant Protection Research Institute, Handbook No. 14. Agricultural Research Council, Pretoria.

Johannsmeier, M.F. 2005. BEEPLANTS of the South-Western Cape. Nectar and pollen sources of honey bees (revised and expanded). Plant Protection Research Institute Handbook No. 17, Agricultural Research Council, Pretoria.

Klein, A.M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I, Cunningham, S.A., Kremen, C. and Tscharntke, T. 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society* 274: 303-313.

Kremen, C. and Ricketts, T. 2000. Global perspectives on pollination disruptions. *Conservation Biology* 14: 1226–1228.

Kremen C, Williams NM, Thorp RW. 2002. Crop pollination from native bees at risk from agricultural intensification. *Proceedings of the National Academy of Sciences* 99(26):16812-16816.

Levy, S. 2011. What's best for bees. *Nature* 479: 164-165.

Lin, B.B., Perfecto, I. and Vandermeer, J. 2008. Synergies between agricultural intensification and climate change could create surprising vulnerabilities for crops. *BioScience* 58(9): 847-854.

Lautenbach, S., Seppelt, R., Liebscher, J. and Dormann, C.F. 2012. Spatial and temporal trends of global pollination benefit. PLoS ONE 7(4): e35954. doi:10.1371/journal.pone.0035954

McGregor, S.E. 1976. Insect Pollination of Cultivated Crop Plants, U.S.D.A. Handbook 496. Washington: U.S. Department of Agriculture, Agricultural Research Service.

Melin, A., Rouget, M., Midgley, J.J. and Donadson, J.S. 2014. Pollination ecosystem services in South African agricultural systems. *South African Journal of Science* 110 (11/12): 1-9.

Morse, R.A. 1991. Bees forever. *Trends in Ecology & Evolution* 6(10): 337-338.

Morse, R.A. and Calderone, N.W. 2000. The value of honey bees as pollinators of U.S. crops in 2000. *Bee Culture* 128: 1-14.

Mouton, M. 2011. Significance of Direct and Indirect Pollination Ecosystem Services to the Apple Industry in the Western Cape of South Africa. MSc Dissertation, Stellenbosch University, Stellenbosch.

Munzhedzi, S. and Motsepe, M. 2013. Climate change and the agricultural sector. Climate and Impacts Factsheet Series, Factsheet 4 of 7. Retrieved: 04 January 2015. Retrieved from: http://www.sanbi.org/sites/default/files/documents/documents/ltas-factsheetclimate-change-and-agriculture-sector2013.pdf

NAMC Report. 2008. 3rd Draft Report. A section 7 committee investigation. The South African Beekeeping Industry. Pretoria, South Africa.

Naug, D. 2009. Nutritional stress due to habitat loss may explain recent honey bee colony collapses. *Biological Conservation* 142: 2369-2372.

Nicolson, S.W. and Human, H. 2012. Chemical composition of the 'low quality' pollen of sunflower (*Helianthus annuus*, Asteraceae). *Apidologie* 44(2): 144-152.

Pirk, C.W.W., Human, H., Crew, R.M. and vanEngelsdorp, D. 2014. A survey of managed honey bee colony losses in the Republic of South Africa – 2009 to 2011. *Journal of Apicultural Research* 53(1): 35-42.

Potts, S.G., Vulliamy, B., Roberts, S., O'Toole, C., Dafni, A., Ne'Eman, G. and Willmer, P. 2005. Role of nesting resources in organising diverse bee communities in a Mediterranean landscape. *Ecological Entomology* 3: 78-85.

Ramankutty, N., Foley, J.A. and Olejniczak, N.J. 2002. People on the land: changes in global population and croplands during the 20th Century. *Ambio* 31(3): 251-257.

Richards, A. J. 2001. Does low biodiversity resulting from modern agricultural practice affect crop pollination and yield? *Annals of Botany* 88: 165-172.

Ricketts, T., Regetz, J., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C., Bogdanski, A.K., et al. 2008. Landscape effects on crop pollination services: are there general patterns? *Ecology Letters* 11(5): 499-515.

Sanford, M.T. 2010. Pollination of citrus by honey bees. Document RFAA092 of the Entomology and Nematology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Schmidt, L. S., J. O. Schmidt, H. Rao, W. Wang, and X. Ligen. 1995. Feeding preference and survival of young worker honey bees (Hymenoptera: Apidae) fed rape, sesame and sunflower pollen. *Journal of Economic Entomology* 88: 1591-1595.

Shigeura, Gordon, James Lee and James A. Silva. 1970. The role of honey bees in macadamia nut (Macadamia integrifolia Maiden and Betche) production in Hawaii. *Journal of the American Society for Horticultural Science* 95(5): 544-546.

Shigeura, G. T. 1967. Varietal nut set and suggestion of pollination requirement in macadamia. *Proceedings of the 7th Annual Meeting of the Hawaii Macadamia Producers Association* 1967: 28.

Singh, R.P. and Singh, P.N. 1996. Amino acid and lipid spectra of larvae of honey bee (*Apis cerana* Fabr) feeding on mustard pollen. *Apidologie* 27: 21-28.

Southwick, E.E. and Southwick, L-Jr. 1992. Estimating the economic value of honey bees (Hymenoptera: Apidae) as agricultural pollinators in the United States. *Journal of Economical Entomology* 85: 621-633.

Stanghellini, M.S., Ambrose, J.T. and Schultheis, J.R. 1998. Seed production in watermelon: a comparison between two commercially available pollinators. *HortScience* 33: 28-30.

Sumner, D.A. and Boriss, H. 2006. Bee-conomics and the Leap in Pollination Fees. Agricultural and Resource Economics Update Vol. 9, No. 3.

Tilman, D., Balzer, C., Hill, J. and Befort, B.L. 2011. Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences* 13 (108): 5020260-20264.

Watanabe, M.E. 1994 Pollination worries rise as honey bees decline. *Science* 265 (5176): 1170.

Westerkamp, C., and Gottsberger, G. 2000. Diversity pays in crop pollination. Crop Science 40(5): 1209-1222.

Winfree, R., Aguilar, R., Vázquez. D.P., Lebuhn, G. and Aizen, M. 2009. A meta-analysis of bees' responses to anthropogenic disturbance. *Ecology* 90(8): 2068-2076.

vanEngelsdorp, D. and Meixner, M.D. 2010. A historical review of managed honey bee populations in Europe and the United States and the factors that may affect them. *Journal of Invertebrate Pathology* 103: 580-595.

Chapter 6

Colony maintenance and swarm trapping: unrecognised forage use ecosystem services for managed honey bees

6.1 A provision ecosystem service perspective

The Millennium Ecosystem Assessment (MA) describes ecosystem services as benefits that humans receive from natural ecosystems. The MA further provides us with a classification of such services: supporting, provisioning, regulating, and cultural. Supporting services are necessary for the production of all other ecosystem services, including biomass production, soil formation and retention, and provisioning of habitat. Provisioning services are products obtained from ecosystems, for example, fuelwood and fruits. Regulating services provide well-being for humans by regulating ecosystem processes such as climate, floods and diseases. Cultural services are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, recreation, aesthetic experiences and many others (MA 2005).

Research into these benefits provided by natural ecosystems has gained momentum in the past few years and is widely recognized (Daily, 1997; De Groot *et al*. 2002). Most of these ecosystem services are however still poorly understood as most research focuses mainly on various drivers (Seppelt *et al*. 2011). When it comes to provision ecosystem services, forests and agriculture are major sources (Fezzi *et al*. 2011). However, agriculture depends heavily on other ecosystem services (MA, 2005). Crop pollination provided by insects (e.g. wild/unmanaged honey bees) is one such ecosystem service. In areas where farming is extensive, with little to no natural areas remaining, managed pollinators (mostly honey bees) are brought in to pollinate crops (Kremen *et al*. 2007; Allsopp *et al*. 2008). Honey bees can also benefit from the forage provided by crops during pollination. Surrounding landscapes may also support bees, if managed hives are moved by the beekeeper to use them prior to pollination. Thus, although managed honey bees are not and ecosystem/free service, the forage that supports these colonies can be seen as ecosystem service (Mouton 2011).

6.2 Forage use for colony maintenance

Managed honey bees in South Africa rely strongly on indigenous and exotics – both invasive and non-invasive species, certain flowering crops, and suburban plants to provide important forage (pollen and nectar) to maintain and stimulate population growth throughout the year (Johannsmeier 2001; Allsopp & Cherry 2004; FAO 2007; Mouton 2011; Hutton-Squire 2014). Maintaining colonies refers to when beekeepers place their colonies in a specific area (apiary site) for a certain period of time to access different forage in order to sustain their colony health and strength. Stimulating colonies refers to a particular time period where colonies have been kept under poor nutrition (e.g. before pollination) or weather conditions (e.g. winter season) as a result, they are placed areas with nectar and/or pollen rich forage to get stronger or recover (e.g. after pollination). This is also referred to as colony build up. In this chapter, colony maintenance and build up with be referred to as colony maintenance. Forage such as canola, sunflower, aloe and bloublom are some of the renowned high pollen and nectar yielding plants favoured for building up colonies just before or after the pollination season (Johannsmeier & Mostert 2001). It is important that honey bees get adequately diverse nutrition for brood development and to remain healthy for buffering against diseases (Alaux *et al*. 2010).

6.3 Managed honey bee colony losses

Seasonal and annual managed colony losses are not a new phenomenon (Neumann & Carreck 2010; vanEngelsdorp & Meixner 2010). However, concerns over continued declines have risen over the last decade (Moritz *et al*. 2010). Although such losses differ from continent to continent, recent losses (since 2006) across Europe and North America (Aizen *et al*. 2009), as well as the USA (vanEngelsdorp & Meixner 2010), are concerning. Reporting colony losses is now mandatory in several countries (see Table 6.1 below). Colony losses in the USA tend to be amongst the highest, with a ±30% estimated loss in 2010 (Neumann & Carreck 2010; vanEngelsdorp *et al*. 2012; Steinhauer *et al*. 2014), compared to most European (see Crailsheim *et al*. 2009) and Middle East countries (Haddad *et al*. 2009; Soroker *et al*. 2009). Most countries show general trends on colony losses during winter-summer periods (see Table 6.1), while others simply record total annual losses. Losses vary widely from one country to another, with some countries experiencing increased losses over the last 6 years (Table 6.1). However, gaps in annual data, and the accuracy thereof, makes it difficult to draw out conclusive trends in declines overtime.

Table 6.1: Summary of annual colony losses in various regions and countries for the period 2008-2013. Losses are <u>not</u> divided according to seasonal losses (i.e. winter versus summer).

	Colony loss percentage(%) per year					
Region/Country	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Europe	-	-	*1.8-53	-	-	-
Japan	-	-	*25	-	-	-
Middle East	-	-	*10-85	-	-	-
USA	-	-	*±30			-
Canada	ˇ35	ˇ33.9	ˇ21	ˇ29.3	ˇ15.3	-
	2008-2009	**2009-2010**	**2010-2011**		**2012-2013**	**2013-2014**
Austria	[1]9.3	[2]14.7	-	-	^18.1	
Bosnia-Herzegovina	-	[2]8.6	-	-	^9.7	
Croatia	-	[2]7.4	-	-	^11.1	
Denmark	[1]7.5	[2]15.1	-	-	^21.2	
Estonia	-		-	-	^24.4	
Finland	-	[2]19.6	-	-	^21.3	
Germany	[1]10.4	[2]18.3	-	-	^15.2	
Ireland	[1]21.7	[2]22.4	-	-	^38.9	
Israel	-		-	-	^20	
Italy (Veneto region)	-		-	-	^14.9	
Italy	[1]6.3	[2]29.8	-	-		
Latvia	-		-	-	^21.4	
Lithuania	-		-	-	^18.8	
Netherlands	[1]21.7	[2]29.3	-	-	^14.3	
Norway	[1]7.1	[2]8.8	-	-	^19.7	
Poland	[1]11.5	[2]15.3	-	-	^20.9	
Scotland	-	[2]25.5	-	-	^36.2	
Slovakia	-	[2]7.4	-	-	^9.3	
Sweden	[1]14.6	[2]27.5	-	-	^24.3	-
Switzerland	[1]9.1	[2]20	-	-	^14	-
Belgium	[1]18 ([Ŧ]19.9)	[2]26	-	-	-	-
UK	[1]12.3	-	-	-	-	-
Canada	-	[2]23.8	-	-	ˇ28.6	ˇ25.9
China	-	[2]4.2	-	-	-	-
England/Whales	-	[2]17.5	-	-	-	-
Northern Ireland	-	[2]14.1	-	-	-	-
Republic of Macedonia	-	[2]6.8	-	-	-	-
Slovenia	-	[2]21.1	-	-	-	-
Spain	-	[2]19.2	-	-	-	-
Turkey	-	[2]17.4	-	-	-	-
USA	-	-	-	-	[3]30.6	-
South Africa	-	[x]29.6	[x]46.2	-	-	-

*Neumann & Carreck (2010) Honey bee colony losses (global perspective); ^van der Zee *et al*. (2014) winter losses 2012-13 based for beekeepers owning 1-50 colonies; [1,2]van der Zee *et al*. (2012) mean (%) colony losses for winter of 2008-2009 and 2009-2010 respectively; [3]Steinhauer et al. (2014) Annual colony losses in the USA 2012-2013; [Ŧ]Nguyen *et al*. (2010) Honey bee colony losses in Belgium during the 2008-9 winter; [x]*Pirk et al*. (2014) Managed honey bee colony losses in RSA 2009-2011; and [ˇ]CAPA statement of honey bees losses in Canada 2008; 2009; 2010; 2011; 2012; 2013; 2014.

The reporting of managed honey bee losses is currently not mandatory in South Africa, however, estimated annual colony losses range between 20-30% (Johannsmeier 2001; Allsopp & Cherry 2004; Mouton 2011). In the first ever study documenting consecutive years of monitoring managed honey bee losses in South Africa (see Pirk *et al*. 2014), losses were indicated to be 29.6% (year 2009-2010) and 46.2% for the year 2010-2011 (see Table 5.1). The surveys covered between 5% in 2009 and 18% in 2010 of the estimated 100000 colonies kept by beekeepers. These findings suggest that South African honey bee colony losses are somewhat equal (2009-2011 survey results) or higher (2010-2011 survey) than those recorded in the USA and most parts of Europe, Australia, the Middle East and Japan. However, the knowledge, monitoring and reporting on colony losses is not as extensive as those of the aforementioned countries to draw conclusive comparisons on the severity of losses suffered by South African beekeepers.

Multiple factors and various mechanisms have been found to be responsible for the losses of managed honey bee colonies (see Potts *et al*. 2010; Splee *et al*. 2013; vanEngelsdorp & Meixner 2010). These factors are either synergistic or have an influence on one another. Concurrent with the global crisis of honey bee deaths linked to colony collapse disorder (CCD) (Watanabe 2008; vanEngelsdorp *et al*. 2009), are factors such as: 1) adverse and shifting weather conditions (Parmesan *et al*. 1999; Harrison & Fewell 2002; McMullan & Brown 2005; vanEngelsdorp *et al*. 2008); 2) diseases, parasites, predators and pests (Finley *et al*. 1996; De Jong 1997; Morse & Flottum 1997; Anderson & Trueman 2000; Genersch 2010; Rosenkranz *et al*. 2010); 3) pesticide use in agriculture (Desneux *et al*. 2007; Aliouane *et al*. 2009; Spivak *et al*. 2011); 4) loss of nesting and forage habitat (Brown & Paxton 2009; Naug 2009); 5) seasonal absconding (Winston 1987; Johannsmeier 2001; Mutsaers 2010) and 6) hive theft and vandalism (Begg & Allsopp 2001; Begg & Begg 2002; Du Preez 2010). All of these can contribute to substantial honey bee losses annually for beekeepers.

Although the factors responsible for the reported bee losses differ amongst countries, there are similar patterns where pesticides are used, or where there is inadequate forage resources, and also where migratory versus non-migratory colonies are concerned (Pirk *et al*. 2014; Steinhauer *et al*. 2014). In South Africa, a major concern is the "socio parasitic" dominance of *Apis mellifera capensis* (Cape honey bee) on *Apis mellifera scutellata* (African honey bee) which results in major colony losses annually for beekeepers in the northern, summer-rainfall parts of the country (see Neumann & Hepburn 2002; Neumann *et al*. 2003). And recently (2014), the outbreak of the American Foul Brood in the Western Cape Province. Although the extend of impact this has contributed to colony losses is yet to be quantified, estimates range between 20-40% on losses for the province (Mike Allsopp Pers. Comm.)

6.2.1 Dealing with colony losses

Despite colony losses beekeepers need to maintain their honey production and meet the high demand for commercial crop pollination. This requires them to replenish any lost colonies on a regular basis. In most European countries, as well as in the USA, this has resulted in extensive bee breeding programmes, an established trade in honey bees, and the repeated introduction of *Apis mellifera* (De la Rúa *et al*. 2009). Honey bee breeding and inbreeding can dilute or reduce genetic resilience in honey bee populations (Zayed 2009), while the introduction of non-native bees has been shown to negatively affect indigenous bee species through disruption of pollination systems (Huryn 1997, Goulson 2003; Paini 2004). Introduced honey bee colonies can also increase the spread of diseases and pathogens (Thomson 2004). In contrast, in South Africa and most parts of the African continent, beekeeping is still reliant on the trapping of "wild swarms" of the locally occurring *Apis mellifera* population (Dietemann *et al*. 2009) to replace lost colonies.

Dietemann *et al.* (2009) attributes the "healthy and vibrant" African honey bee populations to the presence of high genetic diversity and a proportionally large remaining wild component, and the absence of selective bee breeding programmes. The South African honey bee population in particular has been resilient against introduced diseases, pests and pathogens compared to their Northern Hemisphere counterparts (Allsopp 2006; Human *et* *al*. 2011). A number of studies have also highlighted the importance of swarm trapping for the South African beekeeping industry in off-setting colony losses and increasing hive stocks (Johannsmeier 2001; Allsopp & Cherry 2004; Du Preez 2010; Mouton 2011).

Swarming is a natural part of the annual lifecycle of African honey bee colonies (Johannsmeier 2001) and reflects seasonal patterns of growth, development and movement of the colony (McNally & Schneider 1992). Swarming normally occurs in early spring-summer, in response to warmer spring and summer temperatures and increased forage resource abundance (Johannsmeier 2001). South African beekeepers exploit this phenomenon by catching swarms in order to replace and increase their colony stocks. The origin of trapped swarms is however unclear, and some would dispute that not all trapped colonies are "wild". Many of the colonies might have perhaps absconded from neighbouring managed colonies and are later trapped by new hive boxes (Allsopp 2006). In South Africa, where both indigenous sub-species of honey bees are managed, an absconded swarm is defined here as a wild swarm (as opposed to feral when not native).

Beekeepers take advantage of swarming of wild and/or unmanaged honey bee populations by trapping them to either increase their current stocks or to make-up for losses incurred during the season (Johannsmeier 2001; Swart 2001; Mouton 2011). Recognising swarm trapping as an ecosystem service have been explored previously (Mouton (2011); Dietemann *et al*. (2009); Melin *et al*. (2014) and Pirk *et al*. (2014). Swarm trapping entails the capture of swarms by using decoy hives (Tribe & Allsopp 2001). Swarming usually occurs when the ability of the queen to inhibit queen production is partially impaired due to overcrowding (Johannsmeier 2001). It is associated with favourable nectar and pollen flows, colony size and brood-nest congestion. The old queen normally departs with majority of the workers and this can at times be followed by more afterswarms. In her study, Mouton (2011) discusses the importance of natural and exotic vegetation for swarm trapping in the Western Cape Province. Therefore, the loss of either forage for colony maintenance or swarm trapping would have negative impacts on the number of managed colonies supported.

In Europe and North America, beekeepers replace lost colonies by either purchasing packaged bees or split existing colonies (vanEngelsdorp *et al*. 2007). However, in South Africa, four main methods are used by beekeepers when replenishing colonies (Clark 2012). These include swarm trapping, purchasing of new colonies, removal of problem colonies and hive splitting. The removal of problem colonies is the removal of unwanted swarms in places where they cause disturbance or pose a threat to humans and animals, while hive splitting involves the splitting of one strong and healthy hive into two colonies. Hive splitting also involves the rearing of queens to be introduced in the new colony (see Swart *et al*. 2001).

Among the four methods, swarm trapping is thought to be the most preferred due to it being more cost effective and less labour intensive than other methods (Mouton 2011). For example, the cost of purchasing new colonies can range between R200.00-R750.00 (ZAR) depending on the strength and health of the hive (Clark 2012). Beekeepers do not prefer removing problem colonies because not only is it time consuming, but it at times requires specialised equipment and also poses safety risks (i.e. bees in hard to reach places). Hive splitting requires intensive hive management and queen rearing practices are often too time consuming and therefore also not preferred for replacing lost colonies (Swart *et al*. 2001).

Although several studies have highlighted that swarm trapping plays a pivotal in colony replenishment (e.g. Pirk e*t al.* (2004), they also caution that swarm trapping may not be sustainable, particularly if: 1) the managed colony losses remain high and 2) there is not enough good forage to maintain wild colonies and trigger swarming. Currently, the preferred swarm trapping practice relies largely on factors imbedded around natural phenomena. For example, for swarming to occur, the colony has to reach a certain development level and this depends heavily on nectar and pollen flows (Johannsmeier 2001). If the two are not adequately available or accessible for the colonies at a particular point in time, the chances of swarming taking place is marginal. This has both a direct and indirect negative impact on the beekeepers' chances of catching their desired swarm numbers.

6.2.2 Patterns in South Africa

Despite the importance of forage used for colony maintenance, swarm trapping, colony loss or dominant method of hive replenishment, there is no comprehensive information available for all provinces across South Africa. Consequently, this chapter aims to answer the following questions using data from the forage questionnaire:

1) Are the forage resources for colony maintenance and swarm trapping mainly from exotic or indigenous?

2) What forage types are important for colony maintenance and swarm trapping in each province of South Africa and how does this vary between provinces? Here, I hypothesise that the different forage types are equally important for colony maintenance and swarm trapping in all provinces.

3) Does the contribution of important forage species or sources as measured by percentage beekeeper use (i.e. those species providing forage for >5% of hives) differ between colony maintenance and swarm trapping? In other words are the same or different forage sources important for the two respective uses?

4) Given more colonies are maintained than are trapped, do beekeepers use the same number of areas for colony maintenance and swarm trapping?

5) How many hives are lost on average and is there any significant variation between provinces?

6) What is the dominant colony replenishment method used, and are there provinces with exceptions?

6.4 Methods

6.4.1 Forage use for colony maintenance and swarm trapping

Data collection

Section A (number of colonies) and section E (forage use patterns) of the forage use survey (outlined in Chapter 2) were considered for the purpose of documenting forage used for colony maintenance and swarm trapping. In section A, beekeepers indicated the total number of colonies they actively manage. For forage type and use, data table of Section E, beekeepers were provided with an outlined list of various plants known to be used by managed honey bees in South Africa (Johannsmeier 2001 & 2005; Allsopp & Cherry 2005;

Mouton 2011). The table also catered for forage sources not on the provided list. Using this, in the colony maintenance category, beekeepers indicated what average percentage of their colonies benefit from a particular forage source. For swarm trapping, beekeepers indicated what percentages of their swarms are trapped on a particular forage type. Colony maintenance and swarm trapping categories each summed up to 100% for average use of forage sources given. For each forage type, closest town was also asked.

Data analysis

Section E data: The average percentage of colonies captured on each forage source indicated the importance of that particular forage source to colony maintenance and swarm trapping. For estimates of colony numbers, the average colony percentages given were reverted to relative colony numbers. For example, if a beekeeper indicates that he has an *x* number of colonies (in section A); then in section E he indicates that on average 20% of his *x* colonies use forage *b* for maintenance/swarm trapping, then the following equation (Equation 1) was applied:

$$\boldsymbol{Relative\ colonies\ for\ maintencance\ or\ swarm\ trapping} = (\mathbf{20\%} \div \mathbf{100}) \times \boldsymbol{Total\ colonies\ owned}\ (\boldsymbol{x}))$$

The number of colonies attributed by different beekeepers of a province to the same forage source used were added together (using derived counts) to calculate that forage source's percentage contribution to colony maintenance or swarm trapping. Chi-square was used to establish whether the frequency of use between the various forage categories were the same or has any level of significance. The significance of differences were determined by Likelihood Ratio X^2 analyses for the six forage types for each province. For this chapter, as done in Chapters 4 and 5, bloom periods are not presented and discussed but listed in Appendix C as the given times (in months) could not be verified for majority of the listed species using existing records (e.g. Johannsmeier 2001 & 2005). All listed areas were forage was accessed were recorded and where more than one locality listed per forage type, the number of colonies for that particular forage was divided by the total number of listed localities. Here, I assumed that those particular colonies use the listed areas equally for the duration of their placement in that area.

6.3.2 Determining colony loss and replenishment method

Data collection

Section C of the Bee forage use survey (Appendix A; and see Chapter 2), was used to gather colony losses and colony replenishment data. Here, beekeepers were asked to indicate on average their annual percentage colony loss, and what is their preferred method for replacing lost colonies. On the questionnaire, four main methods for replenishing in South Africa were listed as: 1) buying new colonies; 2) hive splitting; 3) swarm trapping and 4) removal of problem colonies. Beekeepers were then asked to score, as a percentage, the method they considered the most preferred (all four categories adding to 100%). It was assumed that beekeepers replace the exact amount of colonies lost, as opposed to increasing what they initially had. Therefore beekeepers were not asked to account for exact differences in the amount of colonies lost and those replaced to make up for losses.

Data analysis

Because beekeepers gave average percentages, all percentages were reverted to relative numbers to obtain estimates of colonies lost and replaced. A beekeeper would indicate in Section A the total number of colonies owned, and in Section C average losses as a percentage. Equation 2 below is then applied to calculate estimates of colonies lost and replaced:

$$\boldsymbol{Relative\ colonies\ lost} = (\boldsymbol{Average\ colony\ loss}\ \% \div \mathbf{100}) \times \boldsymbol{Total\ colonies\ owned}$$

The total percentage of lost colonies per province P_i was calculated as:

$$P_i = \frac{m_i}{n_i},$$

Where m_i is the sum of lost colonies in province *i* and n_i is the total number of colonies per province *i*. The 95% confidence intervals around P_i were estimated by approximating a binomial error distribution with a normal distribution, such that:

$$95\%\text{C.I.}(P_i) = P_i \pm 1.96\sqrt{\frac{1}{n_i}P_i(1-P_i)}.$$

For calculating the preferred methods of replacing colonies, the relative colony numbers were calculated similarly as above. For example, if a beekeeper replaced 0% colonies via "new colonies", 20% through "hive splitting" and 60% from "swarm trapping" then the following equation (Equation 3) was applied:

$$\boldsymbol{Replaced\ colonies} = (\boldsymbol{Colonies\ replaced} * (\%\ \boldsymbol{of\ preferred\ method}) \div \mathbf{100}) \times \boldsymbol{Relative\ colonies\ lost}$$

The same calculation was applied for the three other replacement methods. When calculated values from all four replacement methods were added together, they equalled the "Relative colonies lost" value derived from the Equation 2. Each province was kept separate, and the results presented were based on relative colony numbers. The significance of preferred colony replenishment method, for comparisons at both national and provincial level, was tested using a two way ANOVA in the statistical programme R Development Core Team, 2009.

6.5 Results

6.5.1 Comparison of forage use for colony maintenance and swarm trapping between provinces

Forage category

Results obtained indicated exotic forage to be strongly favoured for colony maintenance as they on average support over 70% of the colonies in seven of the nine provinces. The Eastern and Northern Cape were the only exceptions, with indigenous forage supporting 51% and 61% of the colonies, respectively (Table 6.1). For swarm trapping, exotic forage was also strongly favoured compared to indigenous. In fact, 51-100% of swarms in all nine provinces were trapped on exotic forage (Figure 6.2). In provinces such as the Free State, KwaZulu-Natal, Limpopo and the North West, all swarms were exclusive to exotic forage. It was only in Gauteng, the Northern and Western Cape where indigenous forage accounted for at least 30% of trapped swarms (Figure 6.2).

Forage type

Exotic forage for colony maintenance was dominated by the use of Eucalyptus and agricultural crops, except for the Eastern and Northern Cape where indigenous genera supported 40% and 56% colonies, respectively (Figure 6.3). The use of Eucalyptus was also highly significant ($p=<0.001$) in these seven provinces (Table 6.2). Similarly, Indigenous genera was highly significant, with a positive relationship for the Eastern and Northern Cape (Table 6.2). In contrast, Agricultural crops were only highly significant for colony maintenance in KwaZulu-Natal and the Western Cape, although the relationship was negative for KwaZulu-Natal (Table 6.2). Suburban plantings and weeds were generally the least used forage across all provinces, supporting <3% colonies except for Gauteng and North West, respectively (Figure 6.3). However, Chi Square analyses showed no significant use for both categories in each province compared to other provinces even though the significance was negative (Table 6.2). Vegetation units were of significant use in six provinces, although the relationship was negative (Table 6.2).

For swarm trapping, over 40% of the swarms were trapped exclusively on Eucalyptus in seven of the nine provinces with the exception of the Northern and Western Cape (Figure 6.4). Chi-square results also show a high statistically significant ($p<0.001$) use of Eucalyptus in these seven provinces (Table 6.3). In the Northern and Western Cape, agricultural crops (31.6%) and indigenous genera (36.1%) accounted for most trapped swarms respectively. The use of the two forage types for swarm trapping was significant for the Western Cape ($p<0.05$) and highly significant for the Northern Cape ($p<0.001$). Suburban gardens accounted for 30% of the swarms in the Free State, but <7% in other provinces (Figure 6.4). The level of significance varied across provinces although negative throughout, with the exception of Gauteng and North West that were non-significant (Table 6.3). Weeds accounted for swarm trapping in only three provinces. That is the Free State, Norther Cape and Western Cape. However, less than 10% of colonies in all three provinces were trapped on weeds (Figure 6.4). The less to non-use significance was observed for other provinces by the negative relationship in Table 6.3. Similar significance of less to non-use was observed for Indigenous genera in most provinces, except the Northern Cape, as well as Vegetation units with the exception of Gauteng and Western Cape (Table 6.3).

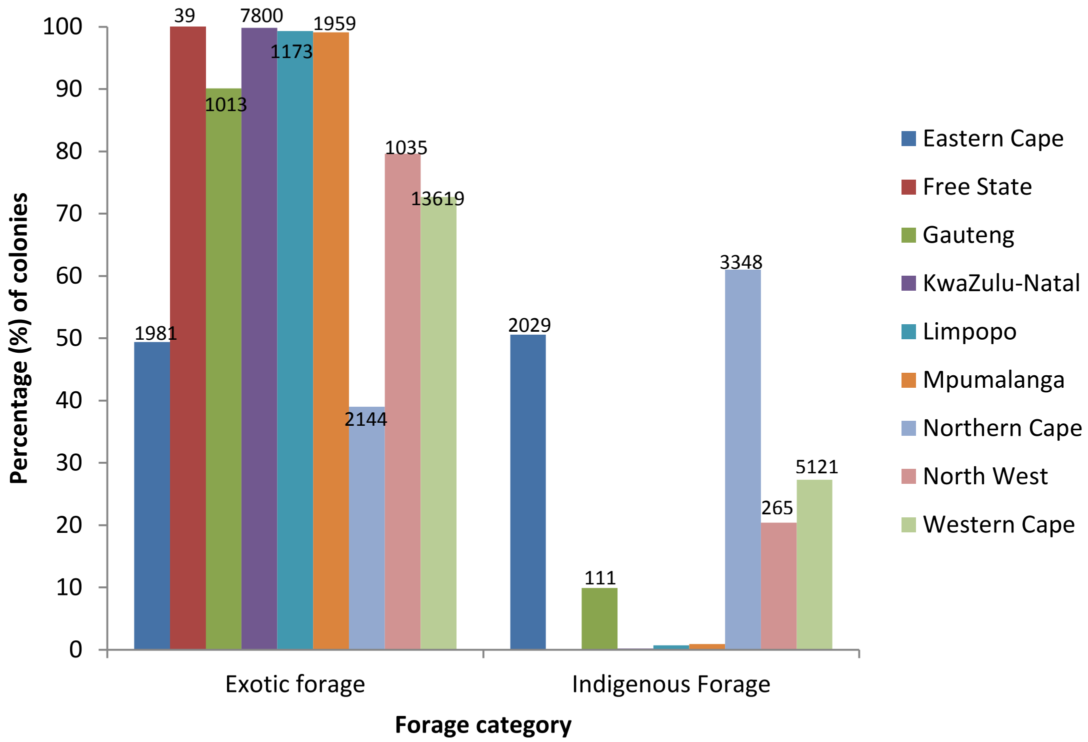

Figure 6.1: Variation in percentage use of exotic versus indigenous forage for colony maintenance across South African provinces. The total number of colonies in a province maintained per forage category is indicated on top of each corresponding bar.

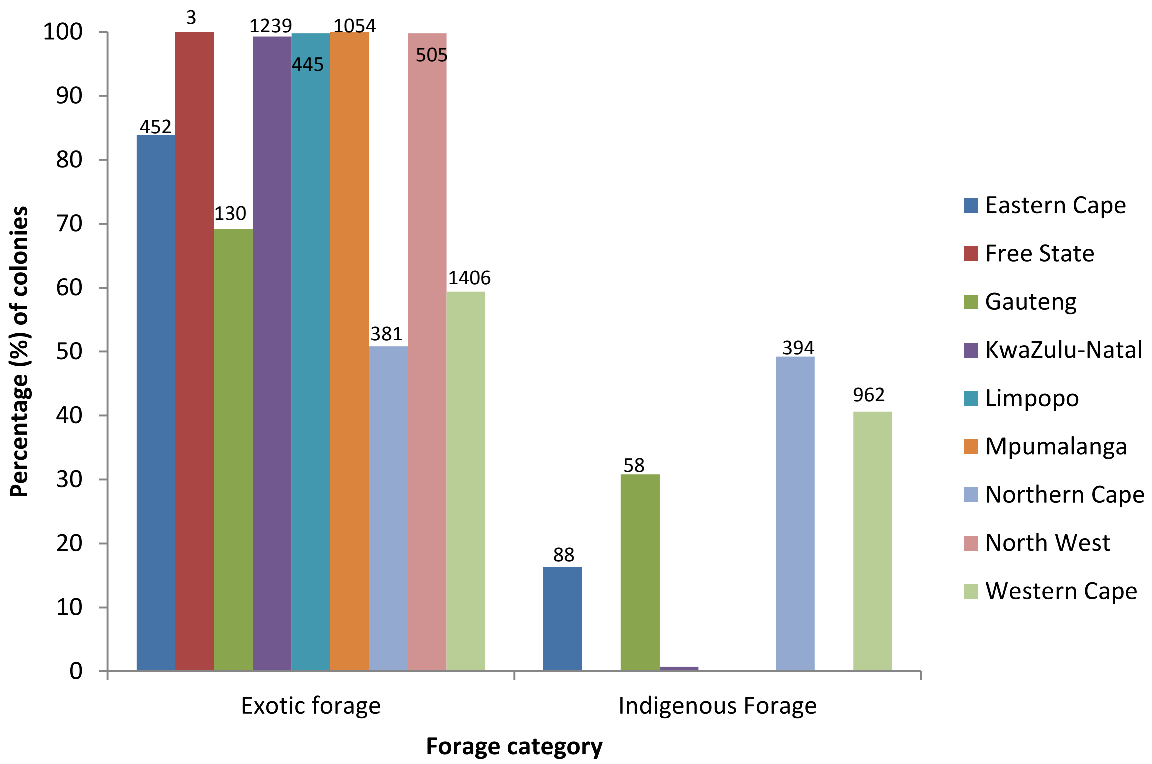

Figure 6.2: Percentage of colonies trapped per forage type across South African provinces. [Total numbers of trapped swarms are indicated on bar graphs – bars without numbers on top have less than nine (9) trapped swarms each].

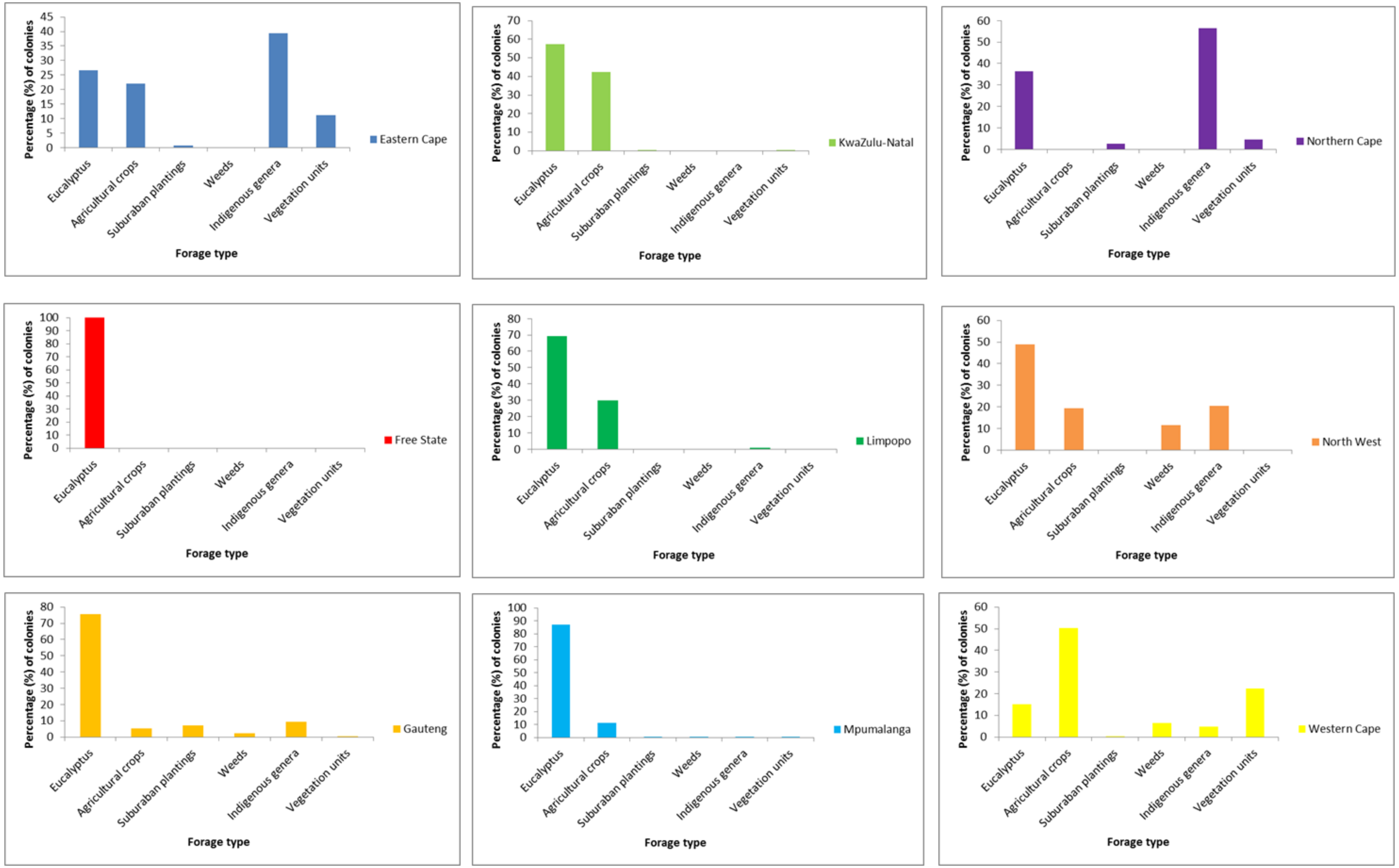

Figure 6.3: Percentage of colonies per forage type used for colony maintenance across South African provinces

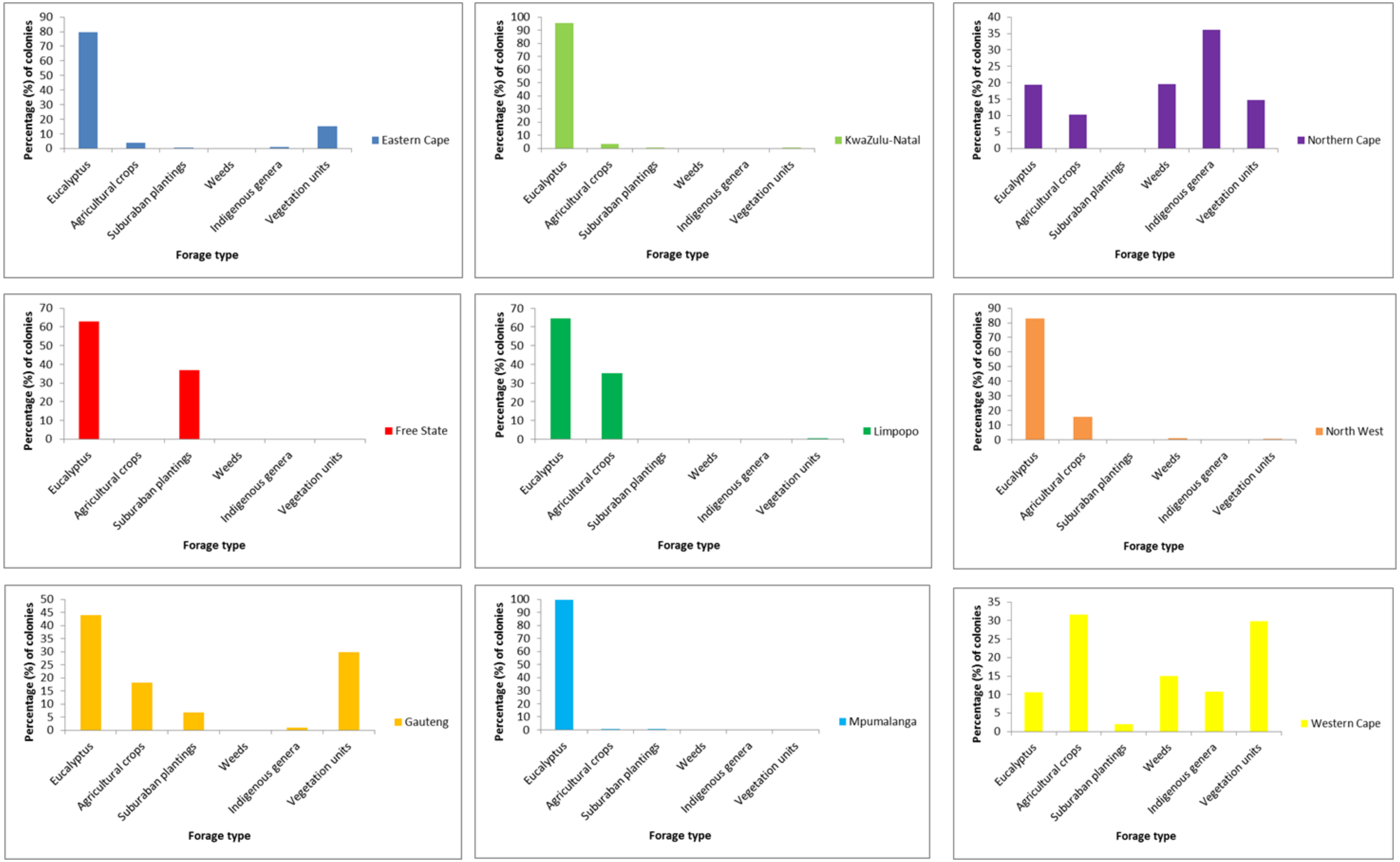

Figure 6.4: Percentage of colonies trapped per forage type across South African provinces

Table 6.2: Forage type frequency variability for colony maintenance in different provinces. The relationship among the forage types is indicated by X^2 and the level of significance by P (p-value, denote by the significance at P < 0.05, 0.01 and 0.001 respectively) and the level of no significance (ns) denoted by α = 0.05.

Province	Eucalyptus		Agricultural crops		Suburban plantings		Weeds		Indigenous genera		Vegetation units	
	X^2	P	X^2	P	X^2	P	X^2	P	X^2	P	X^2	P
EC	6.4(+)	ns	1.7(+)	ns	14.7(-)	<0.05	16.7(-)	<0.01	29.9(+)	<0.001	1.9(-)	ns
FS	416.7(+)	<0.001	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01
GP	211.2(+)	<0.001	8.2(-)	ns	5.6(-)	ns	12.9(-)	<0.05	3.5(-)	ns	14.7(-)	<0.05
KZN	97.6(+)	<0.001	41.6(+)	<0.001	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01
L	164.3(+)	<0.001	10.7(+)	ns	16.7(-)	<0.01	16.7(-)	<0.01	14.7(-)	<0.05	16.7(-)	<0.01
MP	296.8(+)	<0.001	1.9(-)	ns	16.7(-)	<0.01	14.7(-)	<0.05	14.7(-)	<0.05	16.7(-)	<0.01
NC	22.4(+)	<0.001	16.7(-)	<0.01	11.2(-)	<0.05	16.7(-)	<0.01	92.8(+)	<0.001	8.2(-)	ns
NW	62.7(+)	<0.001	0.3(+)	ns	0.7(-)	ns	16.7(-)	<0.01	1.3(+)	ns	16.7(-)	<0.01
WC	0.2(-)	ns	66.7(+)	<0.001	14.7(+)	<0.05	5.6(+)	ns	8.2(+)	ns	1.7(-)	ns

() parenthesis indicates whether the significant level of the relationship slope was positive (+) or negative (-).

Table 6.3: Forage type frequency variability for swarm trapping in different provinces. The relationship among the forage types is indicated by X^2 and the level of significance by P (p-value, denote by the significance at P < 0.05, 0.01 and 0.001 respectively) and the level of no significance (ns) denoted by α = 0.05.

Province	Eucalyptus		Agricultural crops		Suburban plantings		Weeds		Indigenous genera		Vegetation units	
	X^2	P	X^2	P	X^2	P	X^2	P	X^2	P	X^2	P
EC	233.1(+)	<0.001	9.6(-)	ns	14.7(-)	<0.05	16.7(-)	<0.01	14.7(-)	<0.05	0.2(-)	ns
FS	128.8(+)	<0.001	16.7(-)	<0.01	24.8(-)	<0.001	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01
GP	44.8(+)	<0.001	0.1(+)	ns	5.6(-)	ns	16.7(-)	<0.01	14.7(-)	<0.05	10.7(+)	ns
KZN	377.6(+)	<0.001	11.2(-)	<0.05	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	14.7(-)	<0.05
L	136.7(+)	<0.001	20.7(+)	<0.001	16.5(-)	<0.01	16.5(-)	<0.01	16.5(-)	<0.01	16.5(-)	<0.01
MP	416.7(+)	<0.001	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01	16.7(-)	<0.01
NC	0.3(+)	ns	2.7(-)	ns	16.7(-)	<0.01	0.7(+)	ns	22.4(+)	<0.001	0.2(-)	ns
NW	264.0(+)	<0.001	0.0(-)	ns	16.7(-)	<0.01	14.7(-)	<0.05	16.7(-)	<0.01	16.7(-)	<0.01
WC	2.0(-)	ns	13.7(+)	<0.05	13.1(-)	<0.05	0.2(-)	ns	2.0(-)	ns	10.3(+)	ns

() parenthesis indicates whether the significant level of the relationship slope was positive (+) or negative (-).

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Forage sources

Forage source used for both colony maintenance and swarm trapping varied widely across provinces. Also, some provinces (e.g. Gauteng, Northern Cape and North West) had more species numbers than others, but the level of importance (based on percentage of colonies supported) was different (Table 6.4). *Eucalyptus grandis* was the most used species for both colony maintenance and swarm trapping across provinces. However, its importance was high (>49%) only in the Eastern Cape for swarm trapping, and in KwaZulu-Natal, Limpopo and North West for both colony maintenance and swarm trapping (Table 6.4).

Colony maintenance was highly dependent on *Scutia myrtina* (31.2%) in the Eastern Cape, *Eucalyptus sideroxylon* (21%) in Gauteng, *Eucalyptus camaldulensis* (63%) in Mpumalanga, and *Brassica napus* var. *oleifera* (40%) in the Western Cape (Table 6.4). In the Northern Cape, three forage sources (*Eucalyptus camaldulensis*, *Eucalyptus melliodora* and *Zygophyllum* species) were of equal importance for colony maintenance, each supporting 18% colonies. The importance of suburban gardens for colony maintenance was restricted to Gauteng. Coastal and Mountain Fynbos were the only vegetation units listed for use in maintaining colonies in the province comparison (Table 6.4).

For swarm trapping, the Northern and Western Cape provinces had the highest number of significant forage sources, although of differing importance. Several Eucalyptus species dominated the listing as there was at least one Eucalyptus species listed per province. However, their importance for swarm trapping differed for each province (see Table 6.4). Agricultural crops such as macadamia, sunflower, Lucerne and canola were important for swarm trapping in three provinces. Macadamia in particular accounted for 35% and 16% of the trapped swarms in the Limpopo and North West provinces, respectively. Canola was the most important forage source for swarm trapping in the Western Cape, accounting for 30% of the trapped swarms. *Senecio apiifolius*, a weedy species, accounted for 14.5% of the swarms trapped in the Northern Cape. In the Eastern Cape, Gauteng and Western Cape, several vegetation units were listed to be of use for swarm trapping. They constitute between 8-30% of the swarms for respective provinces (Table 6.4). Suburban gardens were of importance for swarm trapping only in Gauteng.

Table 6.4: Comparison of forage sources used for the maintenance of colonies (CM) and swarm trapping (ST) across provinces. Forage source outlined here maintain >5% of the colonies or account for >5% of trapped swarms per province. The Free State province is omitted due to insufficient data for both colony maintenance and swarm trapping. () denotes the number of colonies maintained and [] the number of trapped swarms per province.

Forage type	Forage source	Common name	EC (4010) [540]		GP (1124) [188]		KZN (7817) [1239]		L (1181) [455]		MP (1977) [1054]		NC (5492) [775]		NW (1300) [506]		WC (18740) [2368]	
			% CM	% ST	% CM	% ST	% CM	% ST	% CM	% ST	% CM	% ST	% CM	% ST	% CM	% ST	% CM	% ST
Eucalyptus	*Eucalyptus grandis*	Saligna gum	26.6	74	5.8	5.7	57.2	95.6	69.4	64.4	20.1	21.4	-	-	25	49	11	6.6
	Eucalyptus paniculata	Grey ironbark gum	-	-	20.9	-	-	-	-	-	-	-	-	-	13.5	32.4	-	-
	Eucalyptus sideroxylon	Black ironbark gum	-	-	24.8	-	-	-	-	-	-	-	-	-	5.8	-	-	-
	Eucalyptus melliodora	Yellow box gum	-	-	10.6	-	-	-	-	-	-	-	18.2	9.7	-	-	-	-
	Eucalyptus camaldulensis	River red gum	-	-	12.1	-	-	-	-	-	62.7	78.3	18.2	9.7	-	-	-	-
	Eucalyptus camaldulensis	Red flowering gum	-	-	-	29	-	-	-	-	-	-	-	-	-	-	-	-
Agricultural crops	Citrus spp.	Citrus	17.8	-	-	-	20.9	-	-	-	-	-	-	-	-	-	-	-
	Helianthus annuus	Sunflower	-	-	-	13.3	19.2	-	-	-	-	-	-	-	-	-	-	-
	Macadamia spp.	Macadamia	-	-	-	-	-	-	29.9	35.2	-	-	-	-	19.2	15.8	-	-
	Brassica napus var. oleifera	Canola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40.2	29.9
	Medicago sativa	Lusern/Lucerne	-	-	-	-	-	-	-	-	-	-	-	10.3	-	-	-	-
Weeds	*Raphanus raphanistrum*	Wild radish	-	-	-	-	-	-	-	-	-	-	-	-	11.5	-	-	7.8
	Prosopis spp.	Mesquite/Prosopis	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-
	Echium plantagineum	Echium/Bloublom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.3
Suburban plantings	Suburban gardens		-	-	7.1	6.9	-	-	-	-	-	-	-	-	-	-	-	-
Indigenous genera	*Scutia myrtina*	Cat thorn	31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Acacia/Vachellia karroo	Sweet thorn	6.8	-	-	-	-	-	-	-	-	-	16.6	10.2	-	-	-	-
	Zygophyllum spp.	Zygophyllum spp.	-	-	-	-	-	-	-	-	-	-	18.2	9.7	-	-	-	-
	Aloe grandidentata	Kanniedood	-	-	-	-	-	-	-	-	-	-	13.7	9.7	-	-	-	-
	Aloe greatheadii subsp davyana	Spotted aloe	-	-	-	-	-	-	-	-	-	-	-	-	15.4	-	-	-
	Acacia/Vachellia tortilis	Umbrella thorn	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-
	Senecio apiifolius	Winter weed	-	-	-	-	-	-	-	-	-	-	-	14.5	-	-	-	-

Vegetation units	Coastal Fynbos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	10.8
	Mountain Fynbos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.1	7.7
	Eastern Cape Thicket	-	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Bushveld	-	-	-	29.9	-	-	-	-	-	-	-	-	-	-	-	-
	Karoo	-	-	-	-	-	-	-	-	-	-	-	14.5	-	-	-	-
	Strandveld	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.5
	Mesembs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8
Others	*Other forage sources	17.6	12	18.6	15	3	4.4	0.7	0.4	17	0.4	15	2	9.6	3	31	18

* Percentage total of other forage source that does not support more than 5% of colonies individually in the province or might not be of use for honey crop in the province (see Appendix C for full listing)

6.5.2 Area comparison for colony maintenance and swarm trapping between provinces

The comparison in area use for colony maintenance versus swarm trapping showed that in total more areas were used for swarm trapping (181) compared to colony maintenance (139), although the number of colonies maintained in all these areas (41641) was higher than the number of colonies trapped (7125) (Table 6.5) The Western Cape, Gauteng and KwaZulu-Natal maintain a high area use in both colony maintenance and swarm trapping compared to other provinces. In all provinces, the number of swarms trapped is lower than colonies maintained (Table 6.5).

Table 6.5: Summary (number of respondents, total colonies and total area) of area use for colony maintenance and swarm trapping in South Africa.

Province	Respondents (n)	Total number of colonies		Total localities	
		Colony maintenance	Swarm Trapping	Colony maintenance	Swarm trapping
EC	14	4010	540	9	18
GP	38	1124	188	27	33
KZN	18	7817	1239	19	16
L	38	1181	455	1	6
MP	7	1977	1054	11	10
NC	5	5492	775	6	7
NW	6	1300	506	6	6
WC	87	18740	2368	60	85
Total	**213**	**41641**	**7125**	**139**	**181**

Results for both colony maintenance and swarm trapping did not show direct coloration for number of localities used and colonies per area (trapped or maintained). In both instances, trends of either high densities per fewer areas or smaller densities in more areas were observed (Figure 6.5 and 6.6). For colony maintenance in particular, all provinces had a high average of colonies per area expect for Gauteng Province (Figure 6.5). In fact, Limpopo Province's colonies were all maintained in one area. Mpumalanga and the Northern Cape had the highest averages (>100) for swarm trapping per area compared to other provinces (<85). On average, the area used for colony maintenance (Figure 6.5) and swarm trapping (Figure 6.6) was below two localities per respondent across all provinces.

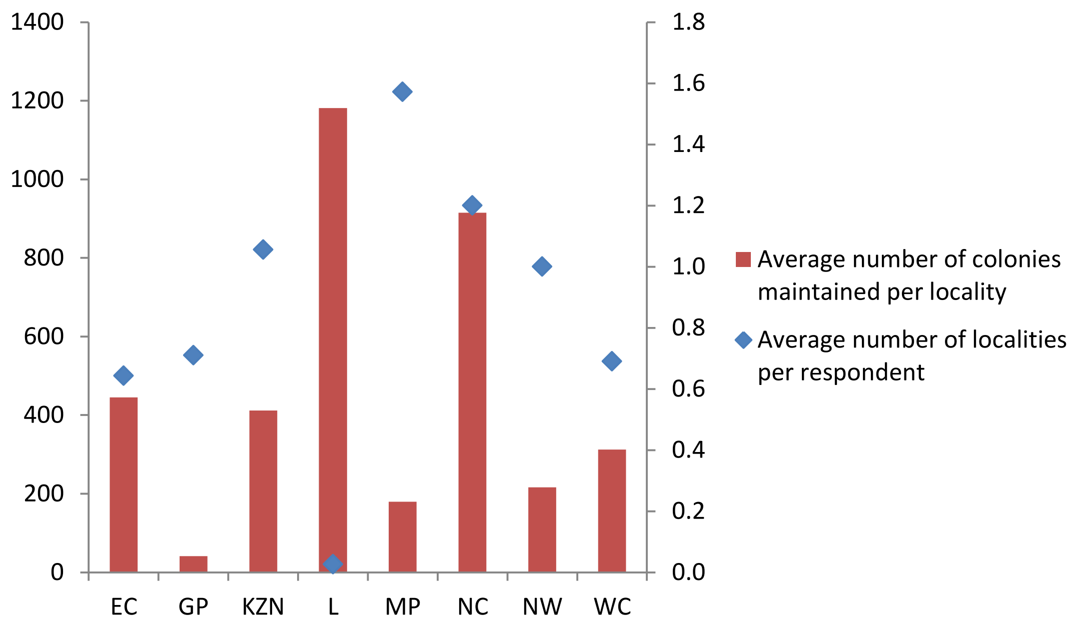

Figure 6.5: Comparison between provinces in area use for colony maintenance based on the average number of colonies per locality (left y-axis) and the average number of localities used per respondent (right y-axis). The Free State Province is omitted due to insufficient information.

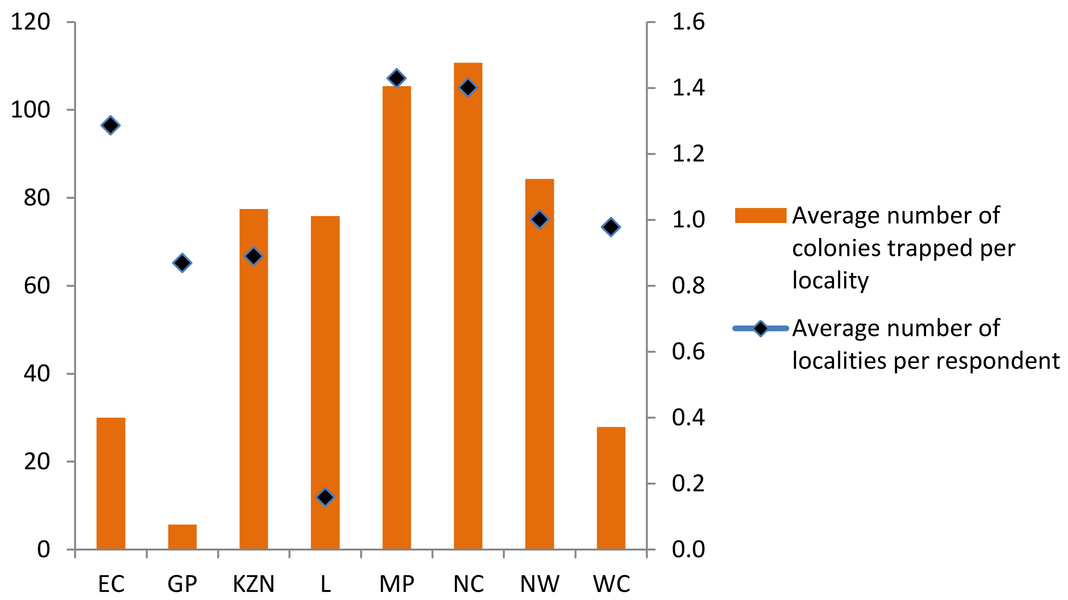

Figure 6.6: Comparison between provinces in area use for trapped swarms based on the average number of colonies trapped per locality (left y-axis) and average number of localities used per respondent (right y-axis). The Free State Province is omitted due to insufficient information.

6.5.3 Variation in colony loss between provinces

A total loss of 10723 (i.e. 21.4 %) colonies was recorded nationally. Mpumalanga, Northern Cape and North West Provinces experienced greater losses (>40%) compared to the other seven provinces (Table 6.6). In contrast, the Free State recorded the lowest loss (3%). The remaining provinces recorded losses ranging from 14% to 24% (Table 6.6).

Table 6.6: Managed colony losses (%) per province and 95% confidence interval (CI). Number of beekeepers (n) and average losses per beekeeper per province (%).

Province	n	Total number of colonies	Colonies lost	
			Number	Percentage (95% CI)
Eastern Cape	14	4298	731	16.9(15.8-18)
Free State	5	210	7	3.3(1.6-6.8)
Gauteng	38	2026	311	15.4(13.9-17)
KwaZulu-Natal	18	8448	1605	19.0(18.2-19.9)
Limpopo	38	1997	475	23.9(22.1-25.8)
Mpumalanga	7	2977	1207	40.5(38.8-42.3)
Northern Cape	5	5562	2535	45.6(44.3-46.9)
North West	6	1361	608	44.8(42.2-47.5)
Western Cape	87	23157	3244	14.0(13.6-14.5)

6.4.4 The dominant colony replenishment method between provinces

Of the 10723 colonies lost annually, 7139 (66.6%) were replaced by swarm trapping, 3116 (29.1%) by hive splitting, 307 (2.9%) by the removal of problem colonies and 161 (1.5%) by purchasing new colonies. When comparing the preference of all four methods using a ANOVA, it was evident that in South Africa swarm trapping was significantly preferred over hive splitting ($F=22.116$, $df=1$, $p<0.001$) and removal of problem colonies ($F=63.093$, $df=1$, $p<0.006$) as opposed to new colonies ($F=3.922$, $df=1$, $p=0.048$).

The high colony rates (60.4-97.8%) trapped using this method in the seven provinces is shown in Figure 6.7. The removal of problem colonies and hive splitting was preferred ahead of swarm trapping for colony replenishment in the Free State and Northern Cape provinces, respectively (Figure 6.7). The purchasing of new colonies was the least applied method for colony replenishment in all nine provinces, making up for <5% of the replaced colonies (Figure 6.7). The ANOVA analysis showed swarm trapping to be significantly more important for colony replenishment, but not across all three other methods for all provinces. In the Eastern Cape, swarm trapping was significantly preferred over hive splitting ($F=81.799$, $df=1$, $p<0.000$), in Gauteng new colonies ($F=4.293$, $df=1$, $p=0.045$) and removals of problem colonies (F=42.248, df=1, p<0.001); in KwaZulu-Natal new colonies (F=50.550, df=1, p<0.001), and North West hive splitting (F=38.343, df=1, p=0.0251).

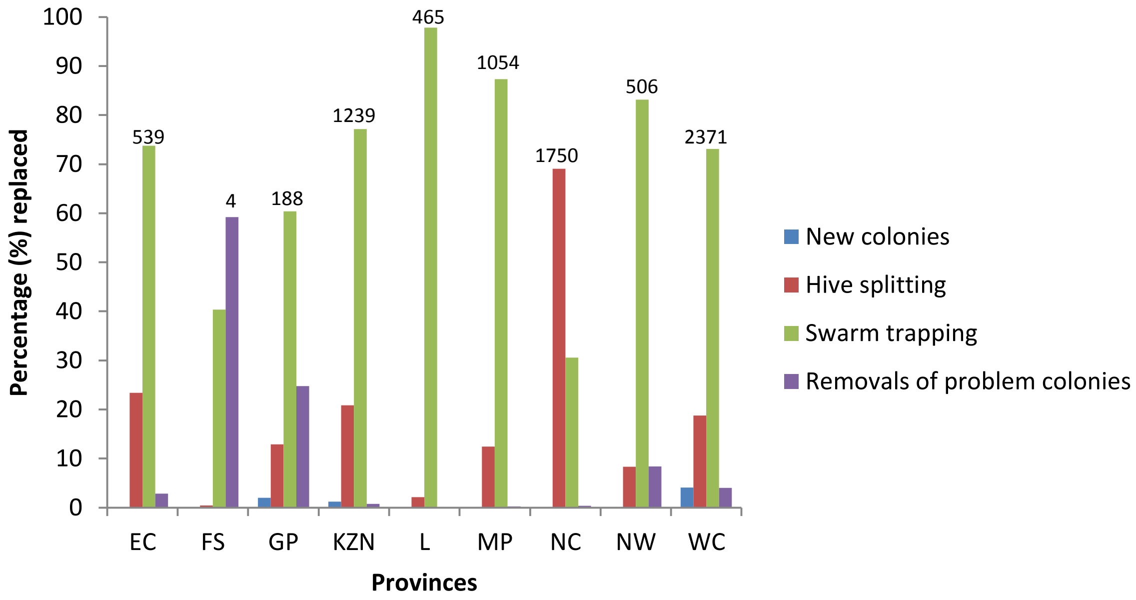

Figure 6.7: Colony numbers replaced per different method across South African provinces. Numbers on green bars indicate the total number of colonies replaced by the trapping of swarms.

6.6 Discussion

6.6.1 Comparison of forage use for colony maintenance and swarm trapping between provinces

This study indicates that although both exotic and indigenous forage for colony maintenance and swarm trapping, exotics are favoured over indigenous forage. For colony maintenance in particular, this was expected as earlier documentations by Johannsmeier (2001) and Hutton-Squire (2014) revealed similar trends of historical forage use in the beekeeping industry. In relation to swarm trapping, Mouton (2011) also made similar observations, although the findings were limited to the Western Cape Province.

When it comes to forage types and individual forage sources, most studies focus specifically on pollen protein and nectar sugar concentration or honey yields (see Damblon & Lobreau-

Collen 1991; Tiwari *et al*. 2010; Nicolson 2011). The contribution of various forage types or individual forage sources to beekeeping practices (such as colony maintenance and swarm trapping) is only vaguely recognised. However, studies by Mouton (2011) and Allsopp & Cherry (2004) are some of the few to investigate forage use related to these practices. Johannsmeier & Mostert (2001) have also outlined several forage sources known to be of value for colony maintenance outside the pollination season. These are said to stimulate brood production, for either long or short periods during the course of the year. These encompass agricultural crops, eucalyptus species, weeds, and indigenous genera (see Johannsmeier & Mostert 2001). Findings here indicated forage types not to be of equal use, importance and significance for both colony maintenance and swarm trapping. This does not support the tested hypothesis. This study also showed the extensive use of plant species and crops within these groups. These tend to provide good pollen and nectar during early spring to summer months, when colonies come out of winter and need to be healthy for pollination as well as the recovery period post pollination (Mouton 2011).

The extensive reliance on several Eucalyptus species in Gauteng and Mpumalanga for colony maintenance further indicates their importance in this regard. The reliable flowering of several Eucalyptus species makes them favourable for beekeeping practices besides honey production (Johannsmeier 2001). Although not previously recorded for preferred use in colony maintenance and swarm trapping, Eucalyptus are widely used for both practices across South Africa's provinces. *Eucalyptus grandis* in particular supported both practices in several provinces (e.g. EC, KZN and MP). This species is well suited for sub-tropical and temperate regions, resulting in its historic planting across the South Africa (Johannsmeier & Mostert 2001).

Citrus, canola and sunflower are not only regarded as major sources of honey, but are essential for colony maintenance because of their high pollen content (Johannsmeier & Mostert 2001). My findings support this. For the Western Cape in particular, canola is crucial for colony maintenance and swarm trapping. Flowering in late winter to early spring, canola serves as good forage to prepare (strengthen) swarms for pollination in summer crops. Sunflower is crucial for carrying colonies into the late summer and remains reliable forage into the winter period. Late summer swarms are also trapped on sunflower, as swarms are attracted by the abundant forage. The importance of citrus in KwaZulu-Natal for colony maintenance can be associated with its high pollen and nectar provision. Macadamia, which has been previously recognised only for low honey yields (Johannsmeier & Mostert 2001), was recorded in this study as important for colony maintenance and swarm trapping. Although restricted to a few provinces, Macadamia supported a substantial numbers of colonies (>15%). The current popular use of agricultural crops for colony maintenance and swarm trapping can be attributed to the expanding planting areas and their yields of good pollen and nectar. At the same time, Alaux *et al*. (2010) warns against the extensive dependence on agricultural crops as they flower for relatively short periods and do not provide a diversified pollen and nectar diet essential for honey bee health.

For weeds, wild radish (*Raphanus raphanistrum*) was the only weed of importance for colony maintenance. Other weeds were recorded for colony maintenance (see Appendix C), but these at only a minimal contribution (<5%). Also, weedy species such as *Echium plantagineum* and *Senecio apiifolius* were important for swarm trapping. Although these species are highly valued among beekeepers for swarm trapping in this study, there is lack of historic documentation for their preference for swarm trapping making it difficult to compare their importance in the past and present. However, the findings in this study emphasises their importance for beekeeping practices (Johannsmeier 2005). It is crucial that their use in beekeeping practices be further investigated and their importance assessed, as they are considered problematic in many areas of South Africa and are the target of clearing operations.

When it comes to indigenous forage (indigenous genera and vegetation units), species of Aloe are depicted as suitable forage for colony maintenance (Johannsmeier 2005). *Aloe greatheadii* var. *davyana (spotted aloe),* in particular is historically highlighted to be one of the key forage sources for colony maintenance in the northern regions of South Africa (Johannsmeier 2001; Human 2006). However, the spotted aloe was in this study only important for colony maintenance in the North West province. Hutton-Squire (2014) observed a change in use of spotted aloe as bee forage. His findings indicate how the species preference has declined over decades and its minimal representation here is therefore not surprising. This could possibly mean that the aloe species is no longer widely available, the area is not accessible or safe for use or that current beekeepers do not value it for the same purpose.

Typical bushveld trees and shrubs were favoured in the Northern Cape for both colony maintenance and swarm trapping. Although, both practices are generally associated with high nectar and pollen yielding plants (Johannsmeier 2001), in the Northern Cape, trees and shrubs used for colony maintenance and swarm trapping are characterised by low pollen and nectar yields (Johannsmeier & Mostert 2001), here beekeepers use them for colony maintenance and swarm trapping. Because they grow in dry climatic conditions, characteristic of the Northern Cape (Mucina & Rutherford 2006), it would seem that beekeepers have very limited forage options and are forced to use what is available (Johannsmeier & Mostert 2001).

Fynbos vegetation in the southern cape is suitable forage for colony maintenance during winter periods when less desired forage is available (Turpie *et al*. 2003; Allsopp & Cherry 2004; Mouton 2011). Fynbos vegetation's high floral diversity results in plants flowering at crucial times of the year (e.g. winter), thus being vital for beekeeping practices such as for colony maintenance (Mouton 2011). No previous records exist for the use of bushveld, fynbos, thicket, karoo and other vegetation units for swarm trapping. However, their listing here makes sense as trapped swarms are indigenous and therefore part of the natural ecosystem. These natural landscapes are suitable for their nesting and foraging requirements.

6.6.2 Area comparison for colony maintenance and swarm trapping between provinces

The variability in pollen and nectar yields by favourable forage sources for different beekeeping practices means that beekeepers often have to travel extensively to access these sources (Johannsmeier & Mostert 2001). At times this is not rewarding financially due to long travelling distances that can expand to neighbouring provinces (Clark 2012). Here we observe the difference in number of areas used for both colony maintenance and swarm trapping (Table 6.2). Colonies maintained and trapped in respective areas also differed provincially. Although the average area use per respondent was generally low (<2), the concentration of colonies maintained and trapped per area was high for most provinces such as Eastern Cape, KwaZulu-Natal, Limpopo and the Northern Cape.

Although it is not clear what constitutes these trends, beekeepers generally use areas closer to them, areas that have easy access, those areas with abundant forage and less impacted by hive theft and vandalism. The high colony density per area also suggests that there is high competition for sites and this has the potential to result in conflict among beekeepers. Where swarm trapping is concerned, the extensively used areas may over time see a decrease in the number of swarms trapped due to overharvesting. This practice is also not monitored or regulated in South Africa. At the same time, wild population sizes or estimates are not known and are difficult to assess (Hawkes & Clarke 2004). Therefore, it is crucial that trapping rates in these areas are closely monitored and assessed on regular basis to pick up any signs of depleting populations.

6.6.3 Variation in colony loss between provinces

This study captured annual losses experienced by beekeepers. Pirk *et al*. (2014) captured losses for 2009-2011. The two studies, however, had different objectives and a different respondent pool of beekeepers. The 21.4% colony losses reported at national level for this study was within range with that of Pirk *et al*. (2014) 2009-2010 (29.6%) recording, but lower to that of 2010-2011 (46.2%). Considering the losses reported in other countries (see Neumann & Carreck 2010; vanEngelsdorp *et al*. 2012; Steinhauer *et al*. 2014; van der Zee *et al*. 2014), South African beekeepers are not experiencing high annual colony losses. Although the investigation into the causes related to the losses were beyond the scope of this study, factors relating can be highly variable (e.g. diseases and pests, lack of forage and extreme weather conditions). The stress associated with colony migration for agricultural crop pollination is also another factor for colony losses (see Pirk *et al.* 2014). The losses outlined in this study are also not based on seasonal variation (i.e. winter versus spring-summer losses) compared to other studies (Nguyen *et al*. 2010; vanEngelsdorp *et al*. 2012; Steinhauer *et al*. 2014; van der Zee *et al*. 2012, 2014).

No clear conclusion can been reached on the impact of these losses for the South African beekeeping industry since the current study only covers a single year of losses. However, when aligning these findings with those of Pirk *et al*. (2014), it is evident that 2010-2011 was a poor year for beekeepers in terms of losses compared to 2009-2010 and 2012. It is arguable that colony losses present unpredictable trends (vanEngelsdorp *et al*. 2009), which can easily be worsened by unforeseen and sporadic events (Huang & Robinson 1995; Amdam & Omholt 2002). Overall, the future inclusion of additional variables and factors covered in van der Zee *et al*. (2012), vanEngelsdorp *et al*. (2012) and Pirk *et al*. 2014) are necessary to assist in unpacking the wide variation in colony losses amongst provinces in future surveys. Furthermore, it is crucial for future investigations to focus on specific regions to help pin point the turning points in any severity of colony losses. Clumping national losses (by averages) often masks loss trends across areas and therefore underestimating losses at a given time. This was evident in the results for individual provinces (e.g. Mpumalanga, Northern Cape and North West) that showed high annual colony losses. These losses are a concern given the low numbers of colonies managed in each of these provinces. It is thus essential to investigate factors leading to the high bee deaths experienced by these provinces.

6.6.4 The dominant colony replenishment method between provinces

Swarm trapping emerged as the primary colony replacement method nationally, although its importance varied across provinces. According to Mouton (2011), this is due to the method being the most economically viable for beekeepers. Furthermore, there are gains in genetic benefits associated with the practice (Dietemann *et al.* 2009). However, the method's strong dependence on readily abundant and available forage sources (Johannsmeier 2001, see above sections), directly translates to it being fragile in instances were forage is not accessible or available (Pirk *et al*. 2004). The risk of diseases and pathogens to threaten wild populations are also a potential threat to swarm trapping (Fürst *et al*. 2014). This is particularly crucial for provinces that lose 30% or more of their colonies annually, as the beekeeper would trap more frequently – needing a faster turn over from wild colonies, making it vital to maintain healthy wild populations and their habitats. High loses, coupled with high trapping rates in potentially unhealthy ecosystem gives little time

for populations to recover and thus rendering the practice possibly unsustainable (Mouton 2011; Pirk *et al*. 2014). These may be limiting factors for beekeeping practices dependent on swarm trapping for colony replenishment in South Africa (Matheson *et al*. 1996).
Hive splitting and the removal of problem colonies could possibly be alternative methods for colony replenishment in South Africa. However, both methods are limited by the intense labour required and potential health hazards such as hard to reach places (Johannsmeier 2001). Although hive splitting can benefit in selecting and improving certain characteristics, especially when introducing reared queens (Swart *et al*. 2001), the success of queen rearing differs between sub-species and the acceptance of a newly introduced queen is generally more successful in younger than older colonies (Johannsmeier 2001). Additionally, the newly split colony should be of good strength in order for it to function optimally (Swart *et al*. 2001). As such, most beekeepers perceive this practice as more labour and financially demanding compared to swarm trapping. The lack of more technologically advanced apicultural techniques within the South African beekeeping industry is possibly an additional hindrance in exploring hive splitting extensively (Mike Allsopp pers. comm. 2014). Limited governmental funding towards research on advancing beekeeping keeping activities and infrastructure hinders the exploration of such techniques (NAMC Report 2008).

Swarm removal also presents difficulties for beekeepers, such as safety risks, as swarms are sometimes at hard to reach places (e.g. roof ceilings) and require specialised equipment to successfully retrieve the swarm. Most beekeepers remove problematic swarms by charging a fee, while others will take the swarm and any honey retrieved as a form of compensation. Removals are highly seasonal, mostly in spring and summer, and are therefore not seen as a reliable form of colony replacement

The replenishment of colonies by buying new colonies may add a financial strain to a beekeeper's operation. The purchase of colonies can amount to almost a seven hundred and fifty Rands per colony, depending on the quality and state of the hive structure, colony size, health, number of brood frames and age (Clark 2012). Also, there has to be a willing seller. In most instances, beekeepers who sell colonies have either trapped an excess of swarms, their beekeeping operations are not productive, have either lost good forage sites or are experiencing high losses due to hive theft and vandalism (Mike Allsopp pers. comm. 2013).

Taking into account the requirements and costs of hive splitting, bee removals and purchasing new colonies, swarm trapping almost certainly becomes the most feasible option. This leads to the assumption that there is generally a lack of better alternatives to swarm trapping as the main method of colony replenishment within the South African beekeeping industry. Mouton (2011), also argues that there are no current better methods to replenish South Africa's managed colonies other than from local "wild" populations. This makes it important to maintain and protect the "wild" honey bee populations and their habitats.

6.7 Conclusion

Findings outlined in this chapter add new detail to forage used for colony maintenance and swarm trapping. In most instances, exotic forage was highly favoured over indigenous. Although forage use varied provincially, due to the varying amount of colonies maintained and trapped, overall eucalyptus and agricultural crops were significantly important forage sources. Indigenous genera use was largely restricted to the Eastern and Northern Cape for colony maintenance, but extended to Gauteng and Western for swarm trapping. Eucalyptus species (e.g. *Eucalyptus grandis*) and agricultural crops (e.g. citrus and canola) were utilized the most in those provinces were exotic forage was favoured. In the Eastern and Northern Cape, indigenous forage use at times matched or even outweighed exotics for colony maintenance and swarm trapping practices. There were also instances were the same species is used for both colony maintenance and swarm trapping, meaning that such species are highly important in those particular provinces for both practices to be possible. Areas used for colony maintenance and swarm trapping were observed to differ provincially, so was the colony numbers maintained and trapped in respective areas. An indication that some areas are more used than others and that also translates to their importance to either colony maintenance or swarm trapping.

Some provinces experienced high colony losses (e.g. Mpumalanga, North West and Northern Cape) compared to others. However, at a national level, losses were within the range of those reported in a recent local study (Pirk *et al*. 2014) and international studies (see Table 6.1). In some instances, beekeepers reported losses far lower than these averages. For the replenishment of colonies, beekeepers indicated that they do make use of all four outlined methods. However, swarm trapping was generally the most favoured across provinces.

6.8 References

Aizen, M.A., Garibaldi, L.A., Cunningham, S.A. and Klein, A.M. 2009. How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. *Annals of Botany* 103: 1579-1588.

Alaux, C., Ducloz, F., Crauser, D. and Le Conte, Y. 2010. Diet effects on honey bee immunocompetence. *Biology Letters* 6:562-565.

Aliouane, Y., El Hassani, A.K. Gary, V., Armenguad, C., Lambin, M. and Gauthier, M. 2009. Subchronic exposure of honey bees to sublethal doses of pesticides. *Environmental Toxicology and Chemistry* 28(1): 113-122

Allsopp, M.H. and Cherry, M. 2004. An assessment of the impact on the bee and agricultural industries in the Western Cape of the clearing of certain Eucalyptus species using questionnaire survey data. Pretoria (South Africa): National Government of the Republic of South Africa, Department of Water Affairs, Internal Final Report.

Allsopp, M.H. 2006. Analysis of *Varroa destructor* infestation of Southern African honey bee populations. MSc Dissertation, University of Pretoria, Pretoria.

Allsopp, M.H., de Lange, W.J. and Veldtman, R. 2008. Valuing Insect Pollination Services with Cost of Replacement. *PLoS ONE* 3(9): e3128. doi:10.1371/journal.pone.0003128.

Amdam, G.V. and Omholt, S.W. 2002. The regulatory anatomy of honey bee lifespan. *Journal of Theoretical Biology* 216: 209-228.

Begg, K. and Begg, C. 2002. The conflict between beekeepers and honey badgers in South Africa: A Western Cape perspective. *The Open Country* N0 4 (Summer 2002): 25-36.

Begg, K. and Allsopp, M.H. 2001. Practical solutions to the beekeeper and honey badger conflict. *South African Bee Journal* 73(3): 135-138.

Brown, M.J.F. and Paxton, R.J. 2009. The conservation of bees: a global perspective. *Apidologie* 40:410-416.

CAPA BEES. 2008-2014. Annual colony loss reports: Retrieved 13 August 2014. Retrieved from: http://www.capabees.com/2014/07/24/capa-statement-on-honey-bees/

Clark, P. 2012. Tales of an African beekeeper: reflections on bees and beekeeping. Charleston , SC. USA.

Daily, G.C. 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington DC.

Damblon, F. and Lobreau-Collen, D. 1991. Bee forage in North and West Africa. 6th Pollination Symposium, *Acta Horticurae* 288: 121-126.

De Groot, R.S., Wilson, M. and Boumans, R. 2002. A typology for the description, classification and valuation of ecosystem functions, goods and services. *Ecological Economics* 41: 393-408.

De Jong, D. 1997. Mites: Varroa and other parasites of brood. In: Morse, R.A. and Flottum, K. (Eds.), Honey Bee Pests, Predators and Diseases. A.I. Root Company,Medina.

Desneux, N., Decourtye, A. and Delpuech, J.-M. 2007. The sublethal effects of pesticides on beneficial arthropods. *Annual Review of Entomology* 52: 81-106.

Dietemann, V., Pirk, C.W.W. and Crewe, R. 2009. Is there a need for conservation of honey bees in Africa? *Apidologie* 40: 285-295.

Du Preez, F.M. 2010. A history of bees and beekeeping in South Africa. Office 444 Govan Mbeki Avenue, Port Elizabeth, South Africa.

FAO. 2007. Crops, Browse and Pollinators in Africa: An Initial Stock-taking. Food and Agricultural Organization of the United Nations. Viale delle Terme di Caracalla, Rome, Italy.

Fezzi, C., Crowe, A., Abson, D., Bateman, I., Askew, T., Munday, P., Pascual, U., Sen, A., Darnell, A. and Haines-Young, R. 2011. Evaluating provisioning ecosystem service values:a scenario analysis for the United Kingdom: Retrieved 12 August 2013. Retrieved from:
http://uknea.unep-wcmc.org/LinkClick.aspx?fileticket=h2WCf1fOqNk%3D&tabid=82

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

Genersch, E. 2010. American Foulbrood in honey bees and its causative agent Paenibacillus larvae. *Journal of Invertebrate Pathology* 103: S10–S19.

Goulson, D. 2003. Effects of introduced bees on native ecosystems. *Annual Review of Ecology, Evolution, and Systematics* 34: 1-26

Hadda, N., Bataeneh, A., Albaba, I., Obeid, D. and Abdulrahman, S. 2009. Status of colony losses in the Middle East. In: *Proceedings of the 41st Apimondia Congress, Mointpellier, France*. Pgs 36.

Harrison, J.F. and Fewell, J.H., 2002. Environmental and genetic influences on flight metabolic rate in the honey bee, Apis mellifera. *Comparative Biochemistry and Physiology Part A* 133: 323-333.

Huang, Z.Y and Robinson, G. E. (1995). Seasonal changes in juvenile hormone titers and rates of biosynthesis in honey bee. *Journal of Comparative Physiology* B 165: 18-28.

Human, H. 2006. Evaluation of the floral reward of *Aloe greatheadii var davyana.* PhD Thesis, University of Pretoria, Pretoria.

Human, H., Pirk, C.W.W. Crewe, R.M. and Dietemann, V. 2011. The honey bee disease American foulbrood – An African perspective. *African Entomology* 19: 551-557.

Hutton-Squire, J.P. 2014. Historical Relationship of the Honey bee (Apis mellifera) and its forage; and the current state of Beekeeping within South Africa. MSc Dissertation, University of Stellenbosch, Stellenbosch.

Johannsmeier, M.F. 2001. Beekeeping in South Africa. Plant Protection Handbook No. 14, Agricultural Research Council, Pretoria.

Johannsmeier, M. F. and Mostert, A. J. N. 2001. South African nectar and pollen flora. In: Beekeeping in South Africa, 3rd edition. Plant Protection Research Institute, Handbook No. 14. Agricultural Research Council, Pretoria.

Johannsmeier, M.F. 2005. BEEPLANTS of the South-Western Cape. Nectar and pollen sources of honey bees (revised and expanded). Plant Protection Research Institute Handbook No. 17, Agricultural Research Council, Pretoria.

Kremen, C., Williams, N.M., Aizen, M.A., Gemmill-Herren, B., LeBuhn, G., Minckley, R., Packer, L., Potts, S.G., Roulston, T., Steffan-Dewenter, I., Vázquez, D.P., Winfree, R., Adams, L., Crone, E.E., Greenleaf, S.S., Keitt, T.H., Klein, A.M., Regetz, J., and Ricketts, T.H. 2007. Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. *Ecology Letters* 10: 299-314.

MA (Millenium Ecosystem Assessment). 2005. Ecosystems and Human Wellbeing. Island Press, Washington, Covelo, London.

Matheson, A., Buchmann, S., O'Toole, C., Westrich, P. and Williams, I. 1996. (Eds). The conservation of bees. Academic Press, London.

Melin, A., Rouget, M., Midgley, J.J. and Donadson, J.S. 2014. Pollination ecosystem services in South African agricultural systems. *South African Journal of Science* 110 (11/12): 1-9.

McNally, L.C. and Schneider, S.S. 1992. Seasonal cycles of growth, development and movement of the African honey bee, *Apis mellifera scutellata*, in Africa. *Insectes sociaux* 39:167-179.

McMullan, J.B. and Brown, M.J.F. 2005. Brood pupation temperature affects the susceptibility of honey bees (*Apis mellifera*) to infestation by tracheal mites (Acarapis woodi). *Apidologie* 36: 97-105.

Morse, R.A. and Flottum, K. 1997. (Eds.) Honey Bee Pests, Predators, and Diseases. A.I. Root Company, Medina, Ohio, USA.

Moritz, R.F.Z., De Marinda, J., Fries, I., Le Conte, Y., Neumann, P. and Paxton, R.J. 2010. Research strategies to improve honey bee health in Europe. *Apidologie* 41: 227-242.

Mouton, M. 2011. Significance of Direct and Indirect Pollination Ecosystem Services to the Apple Industry in the Western Cape of South Africa. MSc Dissertation, Stellenbosch University, Stellenbosch.

Mucina, L. and Rutherford, M.C. (Eds) 2006. The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South African National Biodiversity Institute, Pretoria.

Mutsaers, M. 2010. Seasonal absconding of honey bees (*Apis mellifera*) in tropical Africa. *Proceedings of the Netherlands Entomological Society Meeting* 21: 55-60.

NAMC Report. 2008. 3rd Draft Report. A section 7 committee investigation. The South African Beekeeping Industry.

Naug, D. 2009. Nutritional stress due to habitat loss may explain recent honey bee colony collapses. *Biological Conservation* 142: 2369-2372.

Neumann, P. and Hepburn, H.R. 2002. Behavioural basis for social parasitism of Cape honey bees (*Apis mellifera capensis* Esch.). *Apidologie* 33: 165-192.

Neumann, P, Rudloff, S.E., Pirk, C.W.W. and Hepburn, H.R. 2003. The behavious of drifted Cape honey bee workers (*Apis mellifera capensis*): predisposition for social parasitism? *Apiodologie* 34: 585-590.

Neumann, P. and Carreck, N.L. 2010. Honey bee colony losses. *Journal of Apicultural Research* 49(1):1-6.

Nguyen, B.K., Mignon, J., Laget, D., de Graaf, D.C., Jacobs, F.K., vanEngelsdorp, D., Brostaux, Y., Saegerman, C. and Haubruge, E. 2010. Honey bee colony losses in Belgium during the 2008-9 winter. *Journal of Apicultural Research* 49(4): 337-339.

Nicolson, S.W. 2011. Bee food: The chemistry and nutritional value of nectar, pollen and mixtures of the two. *African Zoology* 46: 197-204.

Paini, D.R. 2004. Impact of the introduced honey bee (*Apis mellifera*) (Hymenoptera: Apidae) on native bees: A review. *Austral Ecology* 29: 399-407.

Parmesan C., Ryrholm N., Stefanescu C., Hill, J.K., Thomas C.D., Descimon H., Huntley B., Kaila L., Kullberg J., Tammaru T., Tennent W.J., Thomas J.A., Warrant M. 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature* 399: 579-583.

Patel, A., Fondrk M.K., Kaftanoglu. O., Emore, C., Hunt, G., Frederick, K. and Amdam, G.V. 2007. The Making of a Queen: TOR Pathway Is a Key Player in Diphenic Caste Development. *PLoS ONE* 2(6): e509. doi:10.1371/journal.pone.0000509

Pirk, C.W.W., Human, H., Crew, R.M. and vanEngelsdorp, D. 2014. A survey of managed honey bee colony losses in the Republic of South Africa – 2009 to 2011. *Journal of Apicultural Research* 53(1): 35-42.

Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O. and Kunin, W.E. 2010. Global pollinator declines: trends, impacts and drivers. *Trends in Ecology and Evolution* 25(6): 345-353.

Randi, E. 2008. Detecting hybridization between wild species and their domesticated relatives. *Molecular Ecology* 17: 285-293.

Rosenkranz, P., Aumeier, P. and Ziegelmann, B. 2010. Biology and control of Varroa destructor. *Journal of Invertebrate Pathology* 103: S96-S119.

Seppelt, r., Dormann, C.F., Eppink, F.V., Lautenbach, S. and Schmidt, S. 2011. A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. *Journal of Applied Ecology* 48: 630-636.

Soroker, V., Hetzroni, A., Yacobson, B., Voet, H., Slabezki, S., Efrat, H. and Chejanovsky, N. 2009. *Colony losses in Israel: incidence of viral infection and beehive populations. In: Proceedings of the 41st Apimondia Congress, Mointpellier, France*. Pgs 38.

Spivak, M., Mader, E., Vaughan, M. and Eullis Jr, N.H. 2011. The plight of the bees. *Environmental Science & Technology* 45:34-38.

Splee, A.M., Lengerich, E.J., Rennich, K., Caron, D., Rose, R., Pettis, J.S., Henso, M., Wilkes, J.T., Wilson, M., Stitzinger, J., Lee, K., Andree, M. Snyder, R. and vanEngelsdorp, D. 2013. A national survey of managed honey bee 2011-2012 winter colony losses in the United States: results from the Bee Informed Partnership. *Journal of Apicultural Research* 52(2): 44-53.

Steinhauer, N.A., Rennich, K., Wilson, M.E., Caron, D.M., Lengerich, E.J., Pettis, J.S., Rose, R., Skinner, J.A., Tarpy, D.R., Wilkes, J.T. and vanEngelsdorp, D. 2014. A national survey of managed honey bee 2012-2013 annual colony losses in the USA: results from the Bee Informed Partnership. *Journal of Apicultural Research* 53(1):1-18.

Swart, D.J., Kryger, P. and Johannsmeier, M.F. 2001. Queen rearing, Chapter 12 in: Johannsmeier MF (Ed.) Beekeeping in South Africa. Plant Protection Research Institute Handbook 14. Agricultural Research Council of South Africa, Pretoria.

Thomson, D. 2004. Competitive interactions between the invasive Europena honey bee and native bumblebees. *Ecology* 85: 458-470.

Tiwari, P., Tiwari, J.k. and Ballabha, R. 2010. Studies on sources of bee-forage for Rock Bee (*Apis dorsata* F.). *Nature and Science* 8(6): 5-15.

Tribe, G.D. and Allsopp, M.H. 2001. Life history of the honey bee colony. Chapter 3, in: Johannsmeier MF (Ed.) Beekeeping in South Africa, 3rd edition. Plant Protection Research Institute, Handbook No. 14. Agricultural Research Council, Pretoria.

Turpie, J. K., Heydenrych, B. J. and Lamberth S. J. 2003. Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation strategies. *Biological Conservation* 112: 233-251.

van der Zee, R., Pisa, L., Andonov, S., Brodschneider, R., Charrière, J-D., Chlebo, R., Coffey, M.F., Crailsheim, K., Dahle, B., Gajda, A., Gray, A., Drazic, M.M., Higes, M., Kauko, L., Kence, A., Kence, M., Kezic, N., Kiprijanovska, H., Krajl, J., Kristiansen, P., Hernandez, R.M., Mutinelli, F., Nguyen, B.K., Otten, C., Özkirim, A., Pernal, S.F., Peterson, M., Ramsay, G., Santrac, V., Soroker, V., Topolska, G., Uzunov, A., Vejsnaes, F., Wei, S.

and Wilkins, S. 2012. Managed honey bee colony losses in Canada, China, Europe, Israel and Turkey, for the winters of 2008-9 and 2009-10. *Journal of Apicultural Research* 51(1):100-114.

van der Zee, R., Brodschneider, R., Brusbardis, V., Charrière, J-D., Chlebo, R., Coffey, M.F., Dahle, B., Drazi, M.M., Kauko, L., Kretavicius, J., Kristiasen, P., Mutinelli, F., Otten, C., Peterson, M., Raudmets, A., Santrac, V., Seppälä, A., Soroker, V., Topolska, G., Flemming, V. and Gray, A. 2014. Results of international standardised beekper surveys of colony losses for winter 2012-2013: analysis of winter loss rates and mixed effects modelling of risk factors for winter loss. *Journal of Apicultural Research* 53(1): 19-34.

vanEngelsdorp, D., Underwood, R.M.,Caron, D.D. and Hayes Jr J. 2007. An estimate of managed colony losses in the winter of 2006-2007: a report commissioned by the Apiary Inspectors of America. *American Bee Journal* 147: 599-603.

vanEngelsdorp, D. Hayes, J. Underwood, R.M. and Pettis, J. 2008. A survey of honey bee colony losses in the U.S., Fall 2007 to Spring 2008. *PLoS ONE* 3(12): e4071. doi:10.1371/journal.pone.0004071.

vanEngelsdorp, D., Evans J.D., Saegerman, C., Mullin, C., Haubruge, E., Nguyen, B.K., Frazier, M. Frazier, J., Cox-Foster, D., Chen, Y., Underwood, R., Tarpy, D.R. and Pettis, J.S. 2009. Colony collapse disorder: A descriptive dtudy. *PLoS ONE* 4(8): e6481.doi:10.1371/journal.pone.0006481.

vanEngelsdorp, D. and Meixner, M.D. 2010. A historic review of manged honey bee populations in Europe and the United States and the factors that may affect them. *Journal of Invertebrate Pathology* 103: S80-S95.

vanEngelsdorp, D., Caron, D., Hayes, J., Underwood, R., Henson, M., Rennich, K., Spleen, A., Andree, M., Snyder, R., Lee, K., Roccasecca, K., Wilson, M., Wilkes, J., Lengerich, E., Pettis, J. and for the Bee Informed Partnership. 2012. A national survey of managed honey bee 2010-11 winter colony losses in the USA: results from the Bee Informed Partnership. *Journal of Apicultural Research* 51(1): 115-124.

Watanabe, M.E. 2008. Colony Collapse Disorder: Many Suspects, No Smoking Gun. *BioScience* 58(5). 385-388.

Winston, M.L. 1987. The Biology of the Honey Bee, Harvard University Press, Cambridge, Mass.

Zayed, A. 2009. Bee genetics and conservation *Apidologie* 40, 237-262.

Chapter 7
Theft and vandalism of managed colonies in the South African beekeeping industry

7.1 Theft and vandalism on managed honey bee colonies

Theft and vandalism are two aspects often overlooked when threats to managed honey bee colonies are assessed, in practise however, they are some of the major problems beekeepers regularly encounter (Johannsmeier 2001; NAMC Report 2008; Du Preez 2010). Where managed colonies are concerned theft can be described in three forms. That is: 1) the removal of the whole hive (box, bees and honey); 2) removal of honey only (bees and hive remain); the removal of honey and bees (only hive box remains). Vandalism refers to the partial or total destruction of the whole hive, whereby the box, bees and honey are lost. Beekeepers experience these threats and they at times appear to be some form of organised theft and vandalism as often all supers of honey are lost and the entire stock of bees is destroyed (Du Preez 2010). Hive theft and vandalism are highlighted to be some of the reasons hindering beekeeping activities in certain areas with good bee forage because hive damage and destruction is prominent with exorbitant costs to beekeepers (NAMC Report 2008). Colony theft and vandalism results in both loss of income and an increase in costs for beekeepers (de Jager 2001). Although Hives are usually, if not always, branded and marked by beekeepers (Johannsmeier 2001), apiary sites are at times in far remote places making it difficult for the beekeeper to enforce precautionary measures and monitoring (Du Preez 2010). Even when beekeepers do put the necessary protective and even preventative measures in place, at extra costs, vandalism and hive theft can never be completely avoided. At times thieves with beekeeping skills are the ones vandalising and stealing hives (Johannsmeier 2001). It is thought that this is done to spite or as result of jealously to other beekeepers as their beekeeping operations might have failed (Mike Allsopp per. comm. 2013). Hive theft is committed by humans (Johannsmeier 2001), while honey badgers (*Melliuora capensis*) are also notorious for vandalising hives (Guy 1972; Begg & Begg 2002). Cases of hive vandalism by Baboons are very uncommon if not accidental (Mike Allsopp per. comm. 2013).

7.1.1 Hive theft and hive vandalism by humans

In 2010, as colony collapse disorder was starting to seriously make its presence known, German beekeepers reported an 85% increase related to beehive theft (alone) prompting the installation of hidden CCTV cameras and satellite tracking devices on their hives (Hall 2010). In Florida, United States of America (USA), beekeepers attribute 3% of their annual colony loses to hive theft and vandalism. Reports on a rise in hive thefts around most parts of the USA has seen companies offering security devices for tracking hive movement, including some that use GPS technology and motion sensors. The California State Beekeepers Association went as far as putting in place a $10,000 Theft Reward Program in order to obtain information on hive theft and vandalism activities taking place around their properties (Eveleth 2013). These are just a few examples of how beekeepers have to deal with further stress of colony losses and financial difficulties in running their beekeeping operations.

South Africa is no exception as cases of hive theft and vandalism are witnessed daily within the beekeeping industry, although not many are reported and fewer are prosecuted (Mike Allsopp per comm. 2013). Beekeepers have tried several methods from hive strapping to protection cages in their efforts of protecting their hives (see Taylor 2000; Johannsmeier 2001; Rust 2004). Although some of these methods are more effective than others, acts of theft and vandalism are persistent (Mike Allsopp per. comm. 2013). In some of the e-mail corresponds on the ApicultureSA and BeesSA googles groups, beekeepers often share their stories of colonies lost due to theft and vandalism. Loses amount to anything between 4-50 hives weekly. Although beekeepers are not covered under the Stock Theft Act for theft of bees or honey even though the initial request was lodged back in 1949 (Du Preez 2010), they are still encouraged to report vandalism and theft together with the total damages suffered. Beekeepers, however insist that they do report such incidents to the Police but nothing positive ever comes from these investigations (Mike Allsopp per. comm. 2013).

Findings of the South African Beekeeping Census conducted in 1974/75 suggested that beekeepers lose about 3440 colonies (or 6%) per annum (then valued at R93 032.00) due to hive theft (Anderson 1977). The Survey of Beekeeping in South Africa conducted by

Conradie & Nortjé (2008) found that on average, 60% of beekeepers countrywide do take precautionary measures in preventing theft and vandalism on their hives. Measures such as electric fencing, wire mesh cages and the employment of armed guards were said to be put in place in protecting their hives. This again highlights the costs associated with apiary site protection and explains why many beekeepers give up on their beekeeping operations completely as a result of persistent hive theft and vandalism (Mike Allsopp per comm. 2013).

7.1.2 Hive damage by animals (e.g. the honey badger)

Generally, hive damage by animals would be overlooked as the damage results from their search for food. Studies by several authors list animal hive damage to be problematic to beekeepers. For example, the honey badger (also commonly referred to as the ratel in South Africa) is well known across most Africa countries for breaking into hives for brood and honey (Begg & Begg 2002). Although honey and brood is not a honey badger's main diet, honey badgers are notorious for raiding hives. They can raid up to twenty hives in one night (Guy 1972; Hepburn & Radloff 1998). According to Begg & Allsopp (2001), the raiding of hives by honey badgers is exacerbated by beekeepers moving their hives into the "badger territory" in their search for valuable forage for their colonies. This was mostly evident in the Western Cape Province as most vandalised hives were found to be more adjacent to natural vegetation (i.e. Fynbos) compared to those placed within orchards and other cultivated areas.

Following the conflicts reported between beekeepers and honey badgers in the Western Cape Province, Begg & Begg (2002) conducted one-on-one interviews with beekeepers to document the extent of damage and confrontations they suffer from honey badgers on a regular basis. This was after studies by Skinner (1985) and Allsopp & Begg (2000) did not yield any positive results due to questionnaires not be completed and returned by beekeepers. In their study, a total of 50 commercial beekeepers constituting 24 600 hives were interviewed. Hive destruction by honey badgers was a common problem with 82% of the beekeepers reporting varying levels of damage resulting from honey badgers (Begg & Begg 2002). Cost associated with such damage was estimated to amount to R500 000.00 per annum in the Western Cape Province by the South African Beekeeping Industry (Begg & Begg 2002) for the period when the study was conducted.

In the effort to protected their hives from honey badgers most beekeepers resorted to killing them (Begg & Allsopp 2001), while others implemented various hive protection methods which seemed more feasible and long term compared to simply killing honey badgers (see Begg & Allsopp 2001; Begg & Begg 2002). Although the damage of managed hives by honey badgers still periodically occurs, there has been considerable progress made in developing and implementing cost-effective non-lethal methods of hive protection against honey badgers in order for beekeeping practices to continue (Begg & Begg 2002).

7.1.3 Current national status of hive theft and vandalism

Hive theft and vandalism continues to occur (Mike Allsopp pers. comm. 2013). As highlighted in the NAMC Report (2008), hive theft and vandalism are some of the major reasons identified for preventing the use of good bee forage in most areas. This however goes beyond just losing access to good bee forage because it forces beekeepers to use marginal forage sites. Marginal forage sites often impact on colony health, and crop pollination readiness, negatively impacting on beekeeper livelihoods (honey sales and pollination services fees) while reducing the number of hives available for pollination services (Mike Allsopp pers. comm. 2013).

This makes it important to assess and understand the current trends and impacts of hive theft and vandalism on the South African beekeeping industry as current estimated general trends of these two threats to beekeeping are currently purely based on numerous assumptions. In particular I document variations in colony losses between provinces with respect to the manner in which they occur. That is through the three categories of theft as well as vandalism. The categories of theft are outlined as: 1) Hive Theft – the removal of the whole hive (box, bees and honey); 2) Honey Theft A – only honey removed (bees and hive remain); 3) Honey Hive Theft B – removal of honey and bees lost (only hive box remains); and 4) Vandalism (Vandalism – destruction of the whole hive (box, bees and honey). I also capture colony losses per area over a five year period as a result of theft and vandalism.

Furthermore, the frequency of acts of theft and vandalism in relation to the apiary site position and visibility in the landscape is investigated.

7.2 Methods

Data collection

Parts of the vandalism and theft questionnaire survey (Appendix B) were used to gather the necessary data required to carry out the objectives of this chapter. The questionnaire was circulated in both Afrikaans and English versions and circulated in the same manner as that of the forage use questionnaire survey (Appendix A) as described in Chapter 2. For the purpose of achieving the objectives of this chapter, only questions 8, 9, 10 & 11 of the theft and vandalism survey are considered and their results presented. Other questions were discarded from the results presentation and discussion due to insufficient responses.

Analysis

Basic descriptive statistical methods are used to present results of questions 8, 9, 10, 11 and 15. Relative numbers of colonies (total for beekeepers) at provincial level are presented. Percentages are given where applicable. For the presentation of result do note the following: 1) **Hive Theft** – the removal of the whole hive (box, bees and honey); 2) **Honey Theft** A– only honey removed (bees and hive remain); 3) **Honey Theft B** – removal of honey and bees lost (only hive box remains) and 4) **Vandalism** – destruction of the whole hive (box, bees and honey).

In this Chapter, all acts of theft and vandalism are attributed to man, as animal damage cannot be classified as vandalism. In addition, beekeepers were not asked to give information on damage caused by animals.

7.3 Results

7.3.1 Variation in colony loss between provinces

Nationally, beekeepers lose a total of 5503 (11%) colonies across the four outlined categories of hive theft as well as vandalism. Vandalism accounted for most loses (45%), followed by Honey theft A (21%), Honey theft B with (19.5%) and lastly Hive theft (15%).

Variations in colony loss between provinces for all four categories showed vandalism to contribute to most losses in five provinces (EC, GP, KZN, NC and WC), followed by Honey Theft B in three provinces (L, MP, NW). Gauteng was the most affected province by vandalism (12%) and Limpopo by Honey Theft B (13%). Losses resulting from Honey Theft and Honey Theft A were only substantial in Limpopo (over 6%). In fact, Limpopo suffered most losses (42%) and Mpumalanga the least (8%). The Free State lost fewer colonies in all categories (one in each) and the data were not meaningful to represent. Other province's losses ranged between 9-20% (Table 7.1).

Table 7.1: Annual percentage of colony losses across provinces due to hive theft and vandalism, then further divided between the four different categories of loss shown as a percentage of total colony loss.

Province	Total number of colonies	Total colony loss (%)	Hive theft (% of total loss)	Honey Theft A (% of total loss)	Honey Theft B (% of total loss)	Vandalism (% of total loss)
EC	3999	15.6	0.8	2.1	3	9.8
GP	1826	20.3	0.9	4.1	3.4	12
KZN	8967	10.8	1.9	3.2	2	3.7
L	1100	42.3	6.8	9.5	13.2	12.7
MP	3090	8.1	2.1	1	2.7	2.3
NC	4562	9.3	0.2	0.1	0.1	8.9
NW	1290	15.7	2.9	4.2	5.9	2.8
WC	23348	9.4	1.7	2.1	1.7	3.8

Free State listed one colony loss in each of the four categories and is not listed here.

7.3.2 Colony losses per area over a five year period

Over a five year period, beekeepers lost a total of 9102 colonies in 134 areas. Vandalism contributed most losses (42%), followed by Hive theft (24%), Honey theft A (18%) and Honey Theft B with (16%). Losses for the Northern Cape were insufficiently accounted for in response to question 9 to be represented, while for the Free State so few colonies were lost that it is not meaningful to use this data here. In most provinces losses where solely within provincial borders. Natal and Gauteng were the only exceptions, losing respectively about a third and more than half of colonies outside the province (Table 7.2). The average number of colonies lost was greatest for the Eastern Cape (129), KwaZulu-Natal (114), and Mpumalanga (159). In contrast, Gauteng suffered the least loses per area (14).

Table 7.2: Total number of hives lost in the last five years and the number of areas where these losses occurred, as well as a comparison of the percentage lost within versus outside each province.

Province	Total colony loses in past five years	Number of areas where losses occur	Average number of colonies lost per area	Percentage (%) of colony losses in areas within province	Percentage (%) of colony losses in areas outside province
EC	1294	10	129	100	0
GP	338	25	14	44	60
KZN	1824	16	114	71	29
L	410	7	59	100	0
MP	635	4	159	100	0
NW	231	5	46	100	0
WC	4292	67	64	100	0

7.3.3 Losses in relation to apiary site position and visibility

Respondents indicated hives to be prone to theft and vandalism across the four landscape categories. Agricultural Lands account for 52.2% of the relative landscape colony loses nationally compared to the other three categories (Table 7.3). Losses of more than 150 colonies occurred in Agricultural Landscapes for seven of the nine provinces (Table 7.3). The Western Cape and KwaZulu-Natal Provinces experienced their highest losses in Agricultural Lands, losing 59% and 71% of colonies respectively. North West Province incurred high losses in Suburban and urban areas (50%) compare to other landscapes, while Eastern Cape beekeepers reported more than half of losses in Natural Vegetation landscapes. In Limpopo, losses were highest in Commercial Pollination landscapes with half of all colonies lost. Losses for the Northern Cape were insufficiently accounted for in response to question 10 to be represented, while for the Free State so few colonies were lost that it is not meaningful to use this data here.

Table 7.3: Annual colony losses relative to the landscape position of colonies kept.

Province	Total losses	Colony loss % across different landscapes			
		Suburban & Urban	Natural Vegetation	Agricultural Land	During Commercial (Paid) Pollination
EC	476	1.1	55.7	43.2	0
GP	332	24.4	28.6	47	0
KZN	887	14.1	9	71.3	5.6
L	410	3.7	0	45.1	51.2
MP	548	18.2	22.8	53.5	5.5
NW	1006	49.7	10.3	29.9	10
WC	2054	17.2	17.8	59	6

Colony loss trends in relation to apiary site visibility varied provincially. However, nationally medium and low visibility contributed to major colony losses (41% and 37%) compared to and high visibility (21%). Limpopo, Mpumalanga, and the Western Cape experience high losses in medium visibility sites, while the Eastern Cape, Gauteng, KwaZulu-Natal and the North West lost most of their colonies in low visibility sites (Table 7.4). Losses for the Northern Cape were insufficiently accounted for in response to question 11 to be represented, while for the Free State so few colonies were lost that it is not meaningful to use this data here.

Table 7.4: Annual colony losses relative to apiary site visibility

Province	Total losses	Colony loss % for different visibility categories		
		High visibility	Medium visibility	Low visibility
EC	436	22.9	13.8	63.3
GP	297	11.4	34.3	54.2
KZN	669	23.3	30.2	46.5
L	330	1.5	77.3	21.2
MP	48	0	75	25
NW	151	26.5	23.2	50.3
WC	1876	26.2	47.1	26.8

7.3.4 Adopted measures to limit/protect against theft and vandalism

Respondents listed a number of varied methods they have in place to curb theft, vandalism and damaged to their hives. The Western Cape recorded the highest number of measures given from 82 responses compared to other provinces. Limpopo Province had the least number of respondents and measures given (Table 7.5). The most common preventative measure was that of placing hives in fenced and secure areas (34), carrying out patrols (10) and the use of cages (12). The enforcement of measures differed provincially, with the beekeepers from the Eastern Cape, Gauteng and Western Cape being in favour of the above mentioned preventative measures (Table 7.5). Extreme measures such as employing armed guards were listed by Eastern Cape and KwaZulu-Natal respondents, as opposed to more general methods of using chains and various forms of strapping listed for other provinces. In the Western Cape, four respondents indicated to have given up on beekeeping due theft and vandalism experienced. Some of the unexpected measures highlighted to be of use in the fight against theft and vandalism included the use of “persona” in threatening those committing such acts. One beekeeper indicated that he simple puts faith and trust in God to protect his hives.

Table 7.5**:** Types of measures used to protect hives from theft, vandalism or damage.

Measures put in place:	Listed measures per province									Total
	EC	FS	GP	KZN	L	MP	NC	NW	WC	
Hives kept in fenced and secure sites	3	2	11	-	1	1	-	-	16	34
Liaise with local leaders, farmers and farm workers	1	-	-	-	-	1	-	-	2	4
Employ armed guards	1	-	-	4	-	-	-	-	-	5
Hives are kept in low visibility areas	1	-	2	1	-	-	1	-	3	8
Build cages around hives	1	-	-	-	-	2	-	1	8	12
Place hives closer to buildings on the farm	-	1	2	-	-	-	-	-	4	7
Change apiary sites	-	1	-	1	-	-	-	-	7	9
Set up traps	-	-	1	2	-	-	-	-	-	3
Strapping hives on wooden frames using steel pegs and binding wire	-	-	1	-	-	-	-	-	-	1
Use a chain locking device and strap of hang hives in trees	-	-	1	-	-	-	-	-	5	6
Carry out regular patrols	-	-	1	-	-	-	2	1	6	10
Hives are in razor wire enclosures, regularly visited and inspected	-	-	2	2	-	-	-	-	5	9
Upgrading fencing around the apiaries	-	-	-	1	-	-	-	-	-	1
Make use of roofs in secure areas	-	-	-	1	-	-	-	-	-	1
Erect fence camps around hives	-	-	-	-	-	1	-	-	-	1
Hives place in spring loaded chains	-	-	-	-	-	-	1	-	-	1
Placing hives in areas with limited human movements	-	-	-	-	-	-	-	1	3	4
Sold all hives	-	-	-	-	-	-	-	-	6	6
Hives in secure area and painted green to blend with the vegetation	-	-	-	-	-	-	-	-	1	1
Hive lids are screwed down so it take time and bumping on the stand aggravates the bees	-	-	-	-	-	-	-	-	2	2
Make use of metal straps	-	-	-	-	-	-	-	-	7	7
Gave up on beekeeping	-	-	-	-	-	-	-	-	4	4
Personal threatening attitude	-	-	-	-	-	-	-	-	1	1
Use wires to seal hives so it takes longer to open	-	-	-	-	-	-	-	-	2	2
Ask God to protect hives	-	-	-	-	-	-	-	-	1	1
Offer rewards	-	-	-	-	-	-	-	-	2	2

7.4 Discussion

7.4.1 Variation in colony loss between provinces

Hive theft and vandalism are not often characterised according to their form of destruction, but rather documented the cause of destruction (i.e. man). Characterising and categorising different forms of theft and vandalism is essential in identifying the likely causes and skills at hand for committing such acts (Johannsmeier 2001, Du Preez 2010). At times, the motive can also be established (Mike Allsopp pers. comm. 2013). Only a handful of studies (see Allsopp & Begg 2000; Begg & Allsopp 2001; Begg & Begg 2002) have focused on animal hive damage that mostly focused on honey badgers. To a certain extent, this excludes Hive Theft, which is exclusive to man in the context of this study.

The findings here showed the severity of losses in each category to differ for each province. This also suggested that the perpetrators of acts of hive theft and vandalism had different motive and skills. This first time quantification of colony losses associated with various categories of hive theft and vandalism suggest vandalism and Honey Theft A, to be the leading modes of hive destruction. This was evident by the high losses incurred in the Northern and Western Cape, Mpumalanga and North West. Although hive destruction captured in the other two categories was slightly lower, hives were still lost and this impacts negatively on overall beekeeping operations. In the case of vandalism, perpetrators mostly vandalise hives to sell either the honey or other components of the hive. In the case of badgers, they use brood as their source of food (Begg & Begg 2002).

7.4.2 Colony losses per area over a five year period

The lack of past documentation on hive theft and vandalism activities has led to no data being available for comparison with the findings of this study. When comparing all four categories, vandalism was again responsible for majority of the losses. A trend also discussed in section 7.4.1. This identifies vandalism as a key threat to beekeeping operations compared to the other categories (i.e. Hive Theft) and has the potential to discourage any beekeeping related activities in certain areas (NAMC Report 2008). Acts of hive theft and vandalism are evidently wide spread across regions given the number of listed areas. Gauteng, KwaZulu-Natal and Western Cape in particular, reported losses had more areas listed. These areas are likely good beekeeping areas, but are casually degraded and compromised for their beekeeping potential due to theft and vandalism.

Of particular interest is that the number of areas listed per province where losses occurred does not match the number of colonies lost in that province. A few areas can have high loses and vice versa. For example, provinces such as the Eastern Cape, Limpopo and Mpumalanga reported fewer areas where colonies were lost compared to Gauteng, KwaZulu-Natal and Western Cape. However, average losses were high in these provinces (see Table 7.2). Although it is not known whether beekeepers had any preventative measures in place over the five year period of reported losses it is without doubt that these high losses will deter beekeeping activities for any area (Johannsmeier 2001).

Beekeepers are well known to migrate their colonies in search of good apiary sites or to render pollination services over short and long distances (vanEngelsdorp *et al*. 2011; Dainat *et al*. 2012). The trend of colony migration, although not asked in the questionnaire, was evident in the colony loss patterns reported. Beekeepers reported losses and listed areas outside their residential provinces. Gauteng and KwaZulu-Natal were examples of such provinces. In Gauteng alone, over 50% of the reported losses occurred outside the provinces' provincial boarders. Du Preez (2010) suggests that migratory colonies are in most instances prone to theft and vandalism compared to stationary colonies because of financial constraints associated with preventative measures. Beekeepers also fail to make regular patrols to keep check of their hives due to long distances required for such purposes (Mike Allsopp pers. comm. 2013).

7.4.3 Losses in relation to apiary site position and visibility

When choosing apiary sites, beekeepers are in most instances bound to use one of the four landscapes categorised in Table 7.3, if not all. Such landscapes usually determine the diversity of pollen and nectar resources that honey bees depend on daily. Suburban and urban landscapes (Costa 2008; Kellison 2009); natural vegetation (Carreck & Williams 1997; Turpie *et al*. 2003), and agricultural Land (which incorporates that used during commercial pollination) (Morse & Calderone 2000; Carvalheiro *et al*. 2010; Levy 2011) all play a role in offering good and nutritional bee forage during various times of the year. These areas are however not without their challenges, which at times impact negatively on managed honey bee colonies.

In this instance, where hive theft and vandalism is the main focus, findings show Agricultural Lands to be the most affected by hive theft and vandalism. In most studies, the dangers of agricultural crops are mostly due to the association of agricultural crops with pesticides that are fatal to bees (see Mullin *et al*. 2010; Long & Morandin 2011; Spivak *et al*. 2011). Here, we witness how two other factors add to the woes of colony losses in agricultural lands. Documented losses in provinces such as the Western Cape, KwaZulu-Natal, Mpumalanga and Limpopo are of great concern given their association with managed honey pollination activities (see Chapter 5).

As much as honey bees depend on most agricultural crops for forage (Levy 2011), growers also depend on managed honey bees for pollination services (Klein *et al*. 2007; Aizen *et al*. 2009; Winfree *et al*. 2011). Therefore, high colony losses in these areas resulting from theft and vandalism are worrying. Also, agricultural areas are meant to be well fenced, manned and thus adequately secured. However, these losses seem to suggest that hives are easily targeted and vandalised. This is perhaps something that beekeepers and growers can work together on to ensure the safety of their hives and crops respectively.

For the suburban and urban landscape, loses were minimal compared to the natural vegetation and agricultural land and this can be attributed to the low number of colonies kept in these areas since urban beekeeping is very minimal in South Africa (Johannsmeier 2001). The good security and constant human movement are also likely to deter acts of hive theft and vandalism. In contrast, Natural Vegetation areas are at times remote (Du Preez 2010) and encroaching onto several animal territories (i.e. Honey badger) thus making hives more susceptible to destruction and vandalism (Begg & Allsopp 2001). Because of their isolation and lack of either human activity or security, it is possible that human perpetrators could easily use this opportunity to steal and even vandalise hives.

Beekeepers always take a few factors into consideration when choosing apiary sites and visibility is one of them (BBKA 2006). This is mostly to ensure that that hives are in a well shaded from high day temperatures (Johannsmeier 2001). The need for easy road access to hives is also critical. At the same time, there should ideally be less human movement around apiary sites (safety reasons) and minimize opportunities for any form of vandalism (Johannsmeier 2001; BBKA 2006). Therefore, apiary visibility has the potential to expose or hide (protect) hives from theft or vandalism. Findings in relation to colony loss relative to visibility in apiary sites suggest medium visible areas to be more prone to theft and vandalism compare to low and high visibility areas.

I had expected highly visible areas to exhibit this effect, since hives would be easily accessible and clearly visible. However, it is likely that medium visibility areas are neither strongly hidden (impenetrable) or highly visible. Therefore creating some form of cover for perpetrators looking to steal or vandalise hives. In highly visible areas, they could easily be spotted from a distance. It is also important to highlight that colony loss patterns with respect to apiary visibility differ from one province to another and that other visibility spectras' can contribute differently to losses. For instance, the Eastern Cape and KwaZulu-Natal experienced greater losses in high visibility apiaries. Visibility spectra's are thus not easily predictable for colony loss as they are associated differently per province with hive theft and vandalism. Also, beekeepers prefer different visibility areas for placing their hives. It is therefore important for beekeepers to understand the pattern of theft and vandalism associated with their current/preferred visibility spectra and familiarise themselves with the threats around those areas in order to take the necessary precautions.

7.4.4 Adopted measures to limit/protect against theft and vandalism

A wide variety of methods have been practiced over decades in order to find suitable measures that limit or even prohibit hive theft and vandalism (Begg & Allsopp 2001; Swart 2001). Although some methods work better than others, the viability of costs remains a challenge to beekeepers (Swart 2001). The use of advanced technological methods such as tracking system and Global Positioning Systems (GPS) is fast growing in most European countries and the United States. However, cost implications are a drawback for South African beekeepers in adopting such methods (Mike Allsopp pers. comm. 2013). Findings captured here highlights previously documented methods to be of common practice amongst beekeepers. Measures relating to fenced/secured areas, carrying out patrols and the use of various cages are dominant on the listings. Cost implications and easy application of such methods are the likely the reason for their preference. Rising fuel prices remain a concern for most beekeepers particularly so for migratory beekeepers who cannot afford to patrol their apiary sites regularly. This is also one of the reason we witnessed major colony losses in those areas far away from beekeepers' home base or province.

According to Swart (2001), the employment of temporary/permanent guards on apiary sites, chaining and locking of hive to structures, and various forms of stripping are a very common practice for beekeepers in securing their hives. Here we see more than 13 respondents from four different provinces (see Table 7.6) opting for such methods in order to prevent hive theft and vandalism on their apiary sites. In reality, most strategies are less feasible than others depending on the size of the beekeeping operation and the kind of hive destruction experienced in respective areas (Conradie & Nortjé 2008). It is for such reasons that beekeepers listed measures extending to the use of persona and prayer with hope of having their hives protected. At the very least, others will just simply give up on beekeeping (Begg & Begg 2002). Hive theft and vandalism prove to be a consistent and very persistent threat to beekeepers across apiary sites. Cost implications for any kind of measure, together with the roll out and maintenance is often a dicing factor for beekeepers in pursing their beekeeping aspirations (Mike Allsopp pers. comm. 2013).

7.5 Conclusion

Hive theft and vandalism is a reality in the South African beekeeping industry. Findings presented here are the first to document various forms of theft and vandalism. These factors differ in how they account for colony loss in respective areas (regions), landscapes and visibility within landscapes. Loss trends also differ from one province to another. However, vandalism was responsible for majority of the losses across areas. These areas were in both their provincial and cross boarder provincial (migratory) apiaries. Also, much of the theft and vandalism took place in agricultural areas and in apiary sites that were of medium visibility. These findings also indicate theft and vandalism to occur even though beekeepers apply or put in place various safety and protective measures.

7.6 References

Aizen, M.A., Garibaldi, L.A., Cunningham, S.A. and Klein, A.M. 2009. How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. *Annals of Botany* 103: 1579-1588.

Allsopp, M.H. and Begg, K. 2000. Research – Badgers and Bees – a survey. *South African Bee Journal 72*(2): 75-79.

Anderson, R.H. 1977. South African Beekeeping Census 1974/75. *South African Bee Journal* 49:7-20.

BBKA. 2006. Choosing an apiary site. British Beekeepers Association Advisory Leaflet Number B11: 1-4.

Begg, K. and Begg, C. 2002. The conflict between beekeepers and honey badgers in South Africa: A Western Cape perspective. *The Open Country* N0 4 (Summer 2002): 25-36.

Begg, K. and Allsopp, M.H. 2001. Practical solutions to the beekeeper and honey badger conflict. *South African Bee Journal* 73(3): 135-138.

Carreck N.L. and Williams I.H. 1997. Observations on two commercial flower mixtures as food sources for beneficial insects in the UK. *The Journal of Agricultural Science* 128: 397-403.

Carvalheiro, L. G., Seymour, C. L., Veldtman, R., Nicolson, S. W. 2010. Pollination services decline with distance from natural habitat even in biodiversity-rich areas. *Journal of Applied Ecology* 47: 810-820.

Conradie, B. and Nortjé, B. 2008. Survey of beekeeping in South Africa. Centre for Social Science Research. Social Surveys Unit. CSSR Working Paper No. 221.

Costa, R.C. 2008. Bee Gardening in Maryland: Providing Forage Plants for Honey Bees in Maryland. Retrieved: 19 May 2011.

Retrieved from: http://www.tonitoni.org/bee_gardening.pdf

de Jager, A.H. 2001. The effect of increasing propolis production on the productivity of the honey bee farming system. MSc Dissertation, Port Elizabeth Technikon, Saasveld - George Campus.

Dainat, B., vanEngelsdorp, D. and Neumann, P. 2012. Colony collapse disorder in Europe. *Environmental Microbiology Reports* 4: 123-125.

Du Preez, F.M. 2010. A history of bees and beekeeping in South Africa. Office 444 Govan Mbeki Avenue, Port Elizabeth, South Africa.

Eveleth, R. 2013. Honey bee Theft Is on the Rise. Retrieved: 26 November 2013. Retrieved from: http://blogs.smithsonianmag.com/smartnews/2013/07/as-times-get-tough-honey bee-theft-is-on-the-rise/

Guy, R.D. 1972. Commercial beekeeping with African bees. *Bee World* 53: 14-32.

Hall, A. 2010. Beekeepers use tracking systems as hive thefts rise. Retrieved: 03 November 2014. Retrieved from: http://www.telegraph.co.uk/news/worldnews/europe/germany/7771634/Beekeepers-use-tracking-systems-as-hive-thefts-rise.html

Hepburn, H.R. and Radloff, S.E. 1998. Honey bees of Africa. Springer, New York, USA.

Johannsmeier, M.F. 2001. Beekeeping in South Africa. Plant Protection Handbook No. 14, Agricultural Research Council, Pretoria.

Kellison, K. 2009. RE: Habitat for Managed and Native Pollinators as Priority Resource Concern for California CStP. Retrieved: 09 May 2011.

Retrieved from: http://pfspbees.org

Klein, A.M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I, Cunningham, S.A., Kremen, C. and Tscharntke, T. 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society* 274: 303-313.

Levy, S. 2011. What's best for bees. *Nature* 479: 164-165.

Long, R.F. and Morandin, L. 2011. Low hybrid onion seed yields relate to bee visits and insecticide use. *California Agriculture* 65: 155-158.

Morse, R.A. and Calderone, N.W. 2000. The value of honey bees as pollinators of U.S. crops in 2000. *Bee Culture* 128: 1-14.

Mouton, M. 2011. Significance of Direct and Indirect Pollination Ecosystem Services to the Apple Industry in the Western Cape of South Africa. MSc Dissertation, Stellenbosch University, Stellenbosch.

Mullin, C.A., Frazier, M. Frazier, J.L., Ashcraft, S., Simonds, R. vanEngelsdorp, D. and Pettis, J.S. 2010. High Levels of Miticides and Agrochemicals in North American Apiaries:

Implications for Honey Bee Health. *PLoS ONE* 5(3): e9754. doi:10.1371/journal.pone.0009754.

NAMC Report. 2008. 3rd Draft Report. A section 7 committee investigation. The South African Beekeeping Industry.

Rust, S. 2004. The beehive protection cage. *South African Bee Journal* 76: 90-92.

Skinner, D.J. 1985. Honey badger research project. *South African Bee Journal* 65:74-80.

Spivak, M., Mader, E., Vaughan, M. and Eullis Jr, N.H. 2011. The plight of the bees. *Environmental Science & Technology* 45:34-38.

Taylor, M. 2000. Container beekeeping. *South African Bee Journal* 72: 32-33.

Turpie, J. K., Heydenrych, B. J. and Lamberth S. J. 2003. Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation strategies. *Biological Conservation* 112: 233-251.

Winfree, R., Gross, B.J. and Kremen, C. 2011. Valuing pollination services to agriculture. *Ecological Economics* 71: 80-88.

vanEgelsdorp, D., Hayes, J., Underwood, R.M., Caron, D. and Pettis, J. 2011. A survey of managed honey bee colony losses in the USA, fall 2009 to winter 2010. *Journal of Apicultural Research* 50(1): 1-10.

Chapter 8
General discussion

8.1 The use of questionnaire surveys

This study was prompted by the discontent which developed between the South African beekeeping industry and the Working for Water Program (WfW), whose intention is to control targeted (problematic) *Eucalyptus* species in the South African landscape (Johannsmeier 2001; Allsopp & Cherry 2004; de Lange *et al.*, 2013). The removal of such species was thought to have the potential of negatively effecting the already ailing beekeeping industry where bee forage is concerned (Allsopp & Cherry 2004). Honey production has been declining annually and beekeepers are finding it difficult to locate adequate forage sites (NAMC Report 2008). Hive theft and vandalism are also on the rise, preventing beekeeping in many potentially good forage areas (NAMAC Report 2008). The lack of bee forage resources and hive theft and vandalism has direct impact on honey bee health as well as beekeeping operations in general. Furthermore, honey bees are used extensively for pollination services in South Africa with highest demands experienced in the deciduous fruit industry of the Western Cape (Allsopp & Cherry 2004; Allsopp *et al*. 2008). However, this is also rapidly changing as crops such as macadamia, avocados and cherries are also increasing in production. As a result, the pollination demand is expected to increase in a short space of time. Globally, managed honey bees (*Apis mellifera*) are regarded as the most important generalist pollinator for a variety of agricultural crops essential for human diet (Klein *et al*. 2007).

In this thesis it was therefore important to investigate the various forage sources that support beekeeping practices (e.g. honey production, pollination services, colony maintenance and swarm trapping) in South Africa, as prior to this study this information was limited and not formally and/or consistently captured. The only two prior publications available for South Africa's bee forage were Johannsmeier (2001) and Johannsmeier (2005). The 2005 publication was exclusively dedicated to bee forage of the South Western Cape. Meaning that there was little to nothing outlined for the other eight provinces. Overtime, forage sites have also been threatened by acts of theft and vandalism. Beekeepers have to constantly come up with extra measures to protect their hives or abandon sites completely. As a result, hive theft and vandalism has become another pressing issue given its reported rise and potential threats it poses to the industry. Also, one cannot discuss the issue of securing, protecting and enhancing forage while the sites on which this forage has to be accessed are not safe for use.

For the purpose of this study, I used two independent questionnaires to gather the required relevant information. The use of a beekeepers questionnaire survey in South Africa has been frequent, given the variation in beekeeper responses and the detailed level of information required. Although distributed simultaneously through the same modes of communication, the surveys had different objectives. The bee forage use questionnaire focused on the use of forage for various beekeeping practices, as opposed to the vandalism and theft questionnaire that was aimed at documenting various acts of theft and vandalism affecting beekeeping practices. Several beekeeping bodies around the world (e.g. New Zealand and Canada) make use of seasonal-annual questionnaires to gather annual information (van der Zee *et al*. 2012; CAPA BEES 2014). Questionnaires are therefore a standard means of gathering information in many social science studies (Eaden *et al*. 1999).

Like most questionnaires, however, this study' questionnaires had limitations. About 2.3% of the completed questionnaires were returned incomplete and had to be discarded. Social instabilities within the beekeeping industry was at the worst level in the year of data collection (2012-2013) resulting in a very high percentage of non-responses despite spreading the two questionnaires as widely as humanly possible (see Chapter 2). Engaging with beekeepers in different provinces during planned meetings and conferences (e.g. the annual "BEECON" conferences – see Chapter 2) was crucial for increasing the initial low return rate. These engagement events were crucial in clarifying several issues for beekeepers (i.e. the rationale, motives and aims of the study) and in strengthening the level of trust in completing the questionnaires voluntary. When dealing with social studies, particularly those with livelihoods implications for the participants, establishing and maintaining such relations is vital (see Conradie & Nortjé 2008; Allsopp & Cherry 2004). Although the surveys showed a higher rate of return (40.4%) compared to the last national survey conducted by Conradie & Nortjé (2008) –22.4%, from recent National Department of

Agriculture stats, this may only represent as little as 30% of the managed honey bee colonies kept in South Africa (Chapter 2). Still, the return rate based on the number of colonies came close to that of the 1978 study conducted by Fletcher & Johannsmeier (1978).

More importantly, however, this study was the first to gather information on beekeepers forage species use (relative quantities used as opposed to Hutton-Squire (2014) which treated listed species at a particular site as of equal importance), crop pollination, as well as theft and vandalism at a national scale. This information is important for baseline data regarding beekeeping trends and practices in the country. It also provides a platform for future research and improves our understanding of the current beekeeping practices used in South Africa. Unfortunately, unlike the survey by Allsopp & Cherry (2004), validation of certain research aspects and questions could not be done given the scope and capacity needed for that. Therefore, the absence of data validation is regarded as the only major limitation for the use of questionnaires in this study.

8.2 The influence of possible bias and false information on the thesis findings

The trustworthiness and credibility of responses generated by questionnaire surveys are often questioned (Babbie & Mouton 2001; Bryman 2012). This is because not all responses can be validated or their truth-value determined (Zwaan 2013). Both these parameters are often used to determine how confident the researcher is with the truth of the findings based on the research design, informants and the context in which the study was conducted. However, the surveying method used in each instance might or might not accommodate the applicability of neither parameter. The latter applies to the two surveys used in this study. However, the assurance of anonymity and the trust-relationship between the beekeepers and myself leads me to believe that truthful and reliable responses were given. Therefore, all data provided by the beekeepers can be trusted. I cannot rule out any bias in their response, as this is generally common with most non face-to-face interviews that normally reduce this effect (Bryman 2012). I believe the data was fitting to the context of all questions asked, their reporting and analysis, as well as discussion and conclusions. No level of bias or untruthfulness, if any, could be tested or determined for the information provided. As a result, all findings presented in each chapter of the thesis are considered to be credible, truthful, trustworthy and unbiased.

8.3 The status and challenges within the beekeeping industry

The beekeeping industry in South Africa is valued at around R20 billion (Clark 2012). This encompasses the production of honey, wax, mead, propolis, swarm removal (all with unknown values) and to crop pollination (10.3 billion, SANBI 2015). Although beekeepers primarily opt for honey production and pollination services, the production of mead and removal of swarms are among other revenue-generating practices. Beekeeper concerns highlighted in their responses were an indication that not much has been done to improve the beekeeping situation in the country since the conclusion of the Section 7 Committee Investigation conducted by the National Agricultural Marketing Council (NAMC) in 2008. Similar concerns raised in this investigation were again captured in this study, with some of the concerns also previously highlighted by Schehle (1996); Allsopp & Cherry (2004); Conradie & Nortjé (2008). From this it is clear that beekeepers to this date (i.e. at the time of answering the forage questionnaire survey) still think that beekeeping in South Africa needs to be improved.

It would be illogical to reiterate the concerns, challenges and recommendations outlined by the NAMAC Report (2008). If the report's findings considered and subsequently have improved matters surrounding industry structures, politics, beekeeper registrations, lack of research and funds, loss of forage and honey imports, these would not be worth asking and discussing (probing beekeepers with this questionnaire) again. However, these are still some of the issues frustrating beekeepers, escalating their mistrust in the government structures meant to assist and support the industry (see Chapter 3). Most beekeepers also believe that the handing over of registration to Department of Agriculture, Forestry and Fisheries (DAFF) has dealt SABIO a huge blow and this can in future deplete SABIO's powers in representing beekeepers. It has long come to light that not all beekeepers want to be registered or their industry to be regulated. In this way, they continue to carry out their practices as they wish in pursuing their personal interests and profits. The lack of proper registration and regulation makes dealing with disease outbreaks and addressing important beekeeping matters difficult (Allsopp & Veldtman 2013). There is to this date still no cooperation and coherent effort to finding solutions.

The longer it takes to pay attention or even address all these issues, the quicker some of these problems escalate. The lack of forage, hive theft and vandalism data are good examples to how quickly the problems worsen. In recent years, forage has decreased drastically (Allsopp & Veldtman 2013) and this is evident by the continued drop in annual honey production locally while the imports increase each year (see chapter 4). Man has replaced honey badgers as the number one culprit in hive vandalism and theft (see chapter7). Yet, not much has been done to fully address these issues. The losses are substantial, amounting to hundreds of thousands of Rands annually. In roughly the same period, American Foul Brood has surfaced again in 2014, since its first unexpected outbreak in 2009, currently constituting 20-40% of colony losses. Had research and further measures been taken or put in place since then, the industry would have been in a better position in dealing with this disease (Allsopp & Veldtman 2013). Until DAFF and relevant bodies concerned confront such challenges and concerns fully, the role players in the industry will continue to drift apart, with current problems possibly escalating while new ones surface. Therefore, to make beekeeping in South Africa the industry it needs to become beekeepers will have to unite and consolidate with the help of proper government support, regulation and enforcement.

8.4 Bee forage: the backbone of beekeeping practices

This study focused not only in documenting various forage used for beekeeping practices, but also how different forage is used and valued across the different practices. It is important to understand this because different forage is used differently for different beekeeping practices. The value of forage thereof varies. These practices (honey production, pollination services, colony maintenance and swarm trapping) were outlined in Chapters 4, 5 and 6 respectively. Bee forage in the form of nectar and pollen is essential for bee health and colony productivity (Alaux *et al*. 2010; Al-Ghamdi *et al*. 2014). Furthermore, the diversity (Levy 2011) and quality (Chauzat *et al*. 2009) of these resources available are equally important. At the same time, plants that yield more nectar than pollen are good for honey crops while those that provide for more pollen are usually preferred for colony build-up and maintenance (Johannsmeier & Mostert 2001). From the study findings, it is clear that managed colonies use both indigenous and exotic forage (see also Hutton-Squire 2014). In Figure 8.1 below, I demonstrate how forage supports beekeeping practices. At the same time, theft and vandalism threatens the optimal use of the forage. The figure is descriptive of the findings and discussion in Chapters 4, 5, 6 and 7.

Honey bee health, honey production and colony maintenance are highly dependent on different forage sources comprised of both indigenous and exotic plant species (Johannsmeier 2001; Mouton 2011; Hutton-Squire 2014). Forage availability and accessibility appear largely impacted by hive theft and vandalism, which occurs in both natural and agricultural areas (Chapter 7). This means that even if an area is a good potential forage site, it must be secure to be ultimately viable for beekeeping (see Chapter 7). In turn, crop pollination and the demand for hives to render pollination service are dependent on three interlinked factors. Firstly, bees need sufficient quality forage to be healthy for crop pollination (Allsopp & Cherry 2004; Mouton 2011). Secondly, the annual planting area of pollinator-dependant crops determines how many hives are required based on the recommended stocking rate and thirdly, if the hives available can meet the required number of hives (see Allsopp *et al*. 2008; Breeze *et al*. 2014).

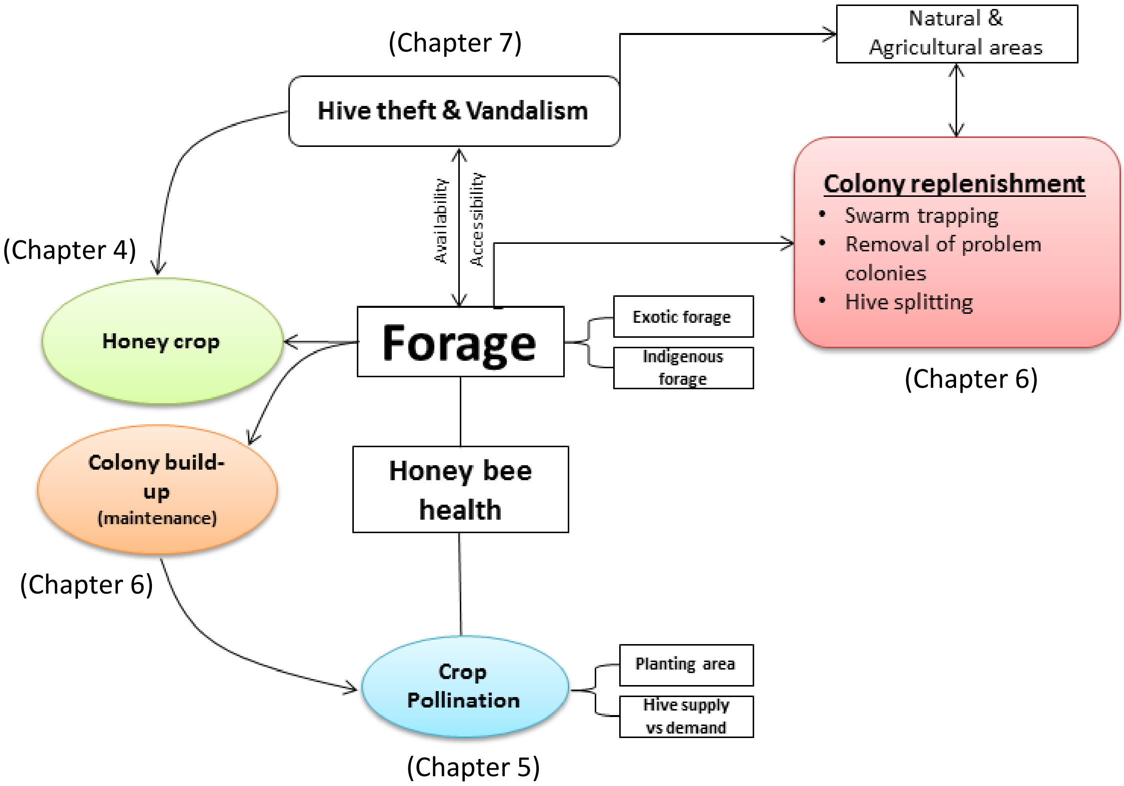

Figure 8.1: Hypothetical flow of various beekeeping practices and their interconnectedness. Diversified forage is the main driver for all beekeeping practices, with its availability and accessibility heavily affected by hive theft and vandalism.

Historically, forage sources were described to be widely variable in their usage given their unreliability (often predictably) in flowering times and availability within the landscape (Attridge 1923, Johannsmeier 2001, Du Preez 2010, Hutton-Squire 2014). While some forage serves as the staple forage source, others are used during dry periods to bridge gaps of forage scarcity (Johannsmeier 2007). This study also proved this to be the case across all beekeeping practices. Various Eucalyptus species and agricultural crops dominated forage use for honey crop, colony maintenance and swarm trapping across almost all (<6) provinces. The importance of different forage species does however differ with respect to the number of colonies they can support at a given time for various beekeeping practices (see Chapter 6). According to Johannsmeier (2001), South Africa does not have many significant and reliable indigenous forage species due to their unreliability in flowering regimes. This was underscored by the preference for exotic forage species by beekeepers.

However, the use of both indigenous and exotic forage species, highlights that no species can solely cater for all beekeeping needs (see also Hutton-Squire 2014).

In contrast to the other provinces, the Eastern and Northern Cape Province had a dominant representation of indigenous forage use for different beekeeping practices compared to other provinces (see Chapters 4, 5 and 6). During pollination, colonies were exclusively dependent on Agricultural crops except in the Eastern and Western Cape (Chapter 5). This raises the question of the quality of nutrition provided by these agricultural fields and what possible impacts they may have on bee health during and post pollination (Brodschneider & Crailsheim 2010). It is discouraged to feed bees exclusively or rely on forage monocultures as it offers less diversity in pollen resources which have implications for bee health (Schmidt *et al*. 1995; Alaux *et al*. 2010).

Nonetheless, crops proved to be more favoured and used (i.e. forage during pollination and colony maintenance) particularly for provinces such as KwaZulu-Natal, Limpopo, Mpumalanga and Western Cape. Consequently, this justifies the need to integrate any environmental management regulations to either retain what forage is currently available or make a concession to expand exotic planting options were appropriate. The Alien and Invasive Species regulations promulgated under the National Environmental Management: Biodiversity Act, 2004 (NEMBA), which was published in the Government Gazette on 01 August 2014 and became law in 01 October 2014, has set the bar in preserving gum species (Government Gazette 2014). The act stipulates that not all gum species in South Africa are considered as invasive, and even those listed not all are targeted for removal pending certain requirements. This is an important step by a Government Department (then DWAF; now DEA) towards recognising that 1) certain gum species provide valuable bee forage and 2) these require downgrading of their invasive status as a means of settling ecosystem service trade-offs (i.e. Forage versus water use).

Critics of alien plant use often argue that alien invasive plants should be replaced by indigenous species at all costs (de Lange *et al*. 2013) - but in terms of bee forage, certain alien species appear to offer many more benefits than indigenous species (Johannsmeier 2001), and choosing to replace them not only has potential economic implications (de Lange *et al*. 2013) but may also degrade the national bee forage resource (Hutton-Squire 2014). No study in South Africa has so far found an indigenous bee forage plant offering equal value as many of the exotic species (see Hutton-Squire 2014). Areas that once offered large tracks of flowering Aloe species (as a winter bee forage), have dwindled in size over the years (see Hutton-Squire 2014). In the Western Cape, production area for canola increase annually – providing ample forage for colonies after winter and just before the pollination season. Beekeepers speak volumes of canola on how it benefits their colonies – yet another exotic species. Moreover, de Lange *et al*. (2013) cautions against the financial implications involved in restoring natural vegetation to match gum forage. In their study they use *Eucalyptus cladocalyx* (sugar gum) as an example and indicate that it would cost almost US$7.5 m per year in supplementary feeding and approximately US$20.2 million per year in Fynbos cultivation/restoration in the search to substitute the forage provisioning service of *E. cladocalyx*. This would have a further knock on effect on commercial crop pollination given that should managed bees fail to render pollination services, estimated cost to replace managed honey bees by hand pollination would range from US$4.5-7.5 million (Allsopp *et al*. 2008; de Lange *et al*. 2013).

Bearing in mind that this forage replacement scenario was based on a single vegetation type and the pollination replacement for only the deciduous fruit industry (de Lange *et al.* 2013), one can postulate costs to be highly exorbitant should it be extended to other exotic species or crops that require forage to be replaced. The time it would take to carry out the restoration or new plantings would also be unrealistic give the immense costs associated (de Lange *et al*. 2013). Although more forage case studies are required to further explore situations were similar trade-offs exist, for now, maintaining and securing the current available forage while promoting means to enhance it should be the main focus.

8.5 Forage distribution and hive migrations

Several studies have investigated the foraging range of honey bees within the landscape, concluding that foraging range is dependent on hive location and the abundance of viable forage source(s) respectively (Visscher & Seeley 1982; Schneider & McNally 1993; Waddington *et al*. 1994; Beekman & Ratnieks 2000; Beekman *et al*. 2004). It is well known that beekeepers move hives mostly when providing pollination services compared to random forage seeking during various times of the year to ensure that their hives have access to good forage sources (Morse & Calderone 2000, vanEngelsdorp & Meixner 2010; Pirk *et al*. 2014). This study identified areas where beekeepers move their colonies to for forage access either for honey crop, during pollination, colony maintenance and swarm trapping. The difference in area use and the importance thereof was further highlighted by the different stocking densities per area (Chapter 6), an indication that some areas are more important that others where forage use is concerned. At the same time, hive movement cannot only be restricted to the desire to accessing targeted forage sources (e.g. Gum woodlots) and the rendering of pollination services, but that vandalism and theft may be other factors forcing beekeepers to abandon and relocate to new apiary sites (Begg & Allsopp 2001).

Beekeepers depending on their residing province used variable areas (different for different beekeeping practices) with respect to each type of beekeeping practice. Some areas were used consistently for honey crop, colony build-up and swarm trapping. Also, some areas had high stocking densities compared to others as was the use by number of beekeepers (see Table 6.3 and Figures 6.5 & 6.6 of Chapter 6). This indicated level of accessibility and importance of forage use in respective areas. In addition, several areas were accessed in areas outside the beekeepers home town and province. For pollination services in particular, this is possibly driven by remuneration while for other beekeeping practices (e.g. honey crop); this is primarily an indication of the effort in obtaining good quality forage irrespective of the travelled distance. This is the first time that such data has been collected whereby the movement of beekeepers is recorded per province for the entire country.

The movement of hives within and across provinces does however require special attention given the possible consequences in the spread of diseases, pests, pathogens and mixing of genetic makeup. The two subspecies of honey bees in South Africa differ from one another in their biogeographical origins (Hepburn & Radloff 2002), morphometric characteristics (Hepburn & Radloff 1998) and in their behavioural and morphological traits (Beekman *et al*. 2008). Legislation regulates movement between different sub-species ranges to prevent hybridizing between the two sub-species (by restricting movement across the demarcated hybrid zone; see Chapter 4 and 5). The mixing of populations of the two sub-species can result in a loss of valuable traits (Zayed 2009), initiate social parasitism (see Pirk *et al*. 2014) and increase the spread of diseases (Smith *et al*. 2013; Fürst *et al*. 2014). Swarm trapping in particular poses a threat since bees trapped in one area (same or different province) are moved to another, with the cycle been repeated annually when the need to trap arises (see chapter 6). This type of practice of movement of the two sub-species needs to be further discouraged, while the investigation of possible measures to better monitor and regulate the practice needs to be encouraged.

8.6 The use of managed hives for commercial crop pollination

Agricultural intensification over the years has reduced the ability of wild pollinators to fulfil agricultural pollination (Aizen & Harder 2009; Klein *et al*. 2007). This has increased the dependence on managed pollinators (e.g. honey bees) to render the necessary pollination service required (Kremen *et al*. 2007; Allsopp *et al*. 2008; Steffan-Dewenter & Westphal 2008; Calderone 2012). In the past decade, declines in insect pollinators have sparked fears over pollination deficits in agricultural crops (Potts *et al*. 2011; Garibaldi *et al*. 2013). However, most countries, like South Africa, lack sufficient data to adequately assess pollination deficits (Melin *et al*. 2014), as well as knowledge in the use of managed honey bees for pollination in South Africa (Johannsmeier 2001; Allsopp & Veldtman 2013). This makes it difficult to draw any conclusions on the supply and demand of hives in commercial crop pollination. This study outlined the numbers of managed colonies used in crop pollination nationally (see chapter 5). At first, it may seem that there are adequate to supply hives nationally to perform pollination services (see Table 5.1, 5.2 and 5.3). However, when taking into account the size of areas planted with pollinator-dependant crops and their pollination requirements (Chapter 5), none of the provinces have sufficient numbers of hives to meet commercial pollination (see Table 5.1, 5.2 and 5.3).

The initial assumptions that arise from data submitted by beekeepers, in terms of the number of hives they rent out for pollination (see Chapter 5). It is important to indicate that the data is questionnaire generated and the numbers given are adopted as such. This is however the best available data (see also Allsopp *et al*. 2008). The lack of records from growers limits comparison which results in data gaps and hinders the calculation of the number of hives used versus those that are available to perform pollination services. The absence of key statistics in planting (production) areas for various crops and their pollination demand also make it difficult to fully account for pollination supply and demand trends (see also Breeze *et al*. 2014).

As mentioned in section 8.3 above, managed pollination services are underpinned by the availability of forage resources (also see Figure 8.1). Therefore, what should be a concern is making available colonies for pollination for a relatively short period during the pollination season; while these same hives have to be maintained outside this period of the season for longer periods the available forage. There needs to be synergy between beekeepers and growers in terms of the supply versus demand in pollination services. At the same time, annual records of planting areas, hives rented and hives placed per hectare need to be kept by provincial departments of agriculture (collected from beekeeper and grower associations) as part of good governance practises (this is currently lacking). This is not only important for monitoring purposes (colony supply vs demand), but also for future planning of crop pollination demand. It is important that this information is available so growers and beekeepers can formulate strategies for keeping adequate numbers of bees healthy outside the pollination season by securing the necessary forage resources. This can only be achieved if current annual pollination demands are known (of which Chapter 5 estimates), together with the size of areas of pollinator-dependant crops in the future.

At the same time, growers cannot simply be content to pay for pollination services, without being aware that these services are underpinned by other ecosystem services (i.e. forage provision), that need separate protection and management (Mouton 2011). Practically, fewer or no managed honey bee hives could mean fewer hectares of planted insect dependant crops (e.g. limited choices available for partonogenic crop cultivars) and/or more expensive produce with contaminant reduction in social welfare (see Galia *et al.* 2009). Therefore, it is important for growers to keep and provide pollination services records, just as it is for beekeepers. Perhaps grower associations and DAFF (also representing the beekeeping industry) need to discuss putting in place regulations that will make it necessary for these records to be kept and made available for research and planning purposes. This will enable more reliable estimates of pollination supply and demands, as well as most importantly forage use planning.

8.7 Hive theft and vandalism

In South Africa, hive destruction has often in the past been caused by honey badgers and baboons (e.g. Begg & Begg 2002). Today, since beekeeping has become a professional business world-wide, humans are the most significant culprits of hive theft and vandalism. These acts of destruction threaten beekeeper livelihoods and restrict beekeeping activities (Johannsmeier 2001; NAMC Report 2008). As demonstrated in Figure 8.1, hive theft and vandalism influences the use of forage in both natural and agricultural areas, and can discourage beekeeping practices in those areas. Safety is a key factor when it comes to the viability and sustainability of beekeeping within South Africa. Beekeepers have invested in some security measures to try and reduce these losses (see Johannsmeier 2001; Begg & Allsopp 2001; Hall 2010).

Because hive theft and vandalism occurs in both natural and agricultural lands, it threatens the normal maintenance of colonies, honey production and crop pollination. It is arguably as big a threat as the loss of forage and therefore addressing this issue is as important as the provision of forage. Law regulations need to recognise hive theft and vandalism as an act of stock theft or vandalism of personal property (Du Preeze 2010). This can also extend to environmental law enforcement, seeing that destruction and loss of managed honey bees has an indirect implication on wild populations. Although one could equally argue that managed beekeeping is a threat to wild honey bees in a sense that introduction of diseases into wild population is a result of the managed honey, the trapping of wild swarms further complicates the understanding of how to best regulate swarm trapping to preserve wild populations. In essence, each time beekeepers lose a portion of their stock, they rely heavily on wild swarm to make up for losses (see chapter 6). Given that losses are already substantial due to diseases, pests and weather conditions (see Allsopp 2006; Pirk *et al.* 2014), hive theft and vandalism further exacerbate the situation.

Land owners need to be extra vigilant and have proper agreements with beekeepers to ensure the safety of hives on their property. During pollination at least it needs to be established as to who is responsible for the safety of hives. A system can be put in place whereby landowners compensate beekeepers if hives are damaged or stolen when rented for pollination, possibly in the form of hive insurance. It would be difficult to enforce this for normal forage access as landowners are not entitled to allow the use of their land for beekeeping. They are in fact doing beekeepers a favour in letting them place their hives on their property. Until such a time that countering hive theft and vandalism becomes a joint effort between beekeepers, landowners and law enforcement authorities, it will be an endless battle against perpetrators. The results presented in chapter 6 demonstrate the seriousness of this issue and the implications thereof, with the ideology of potential solutions, as outlined above, should be considered in addressing hive theft and vandalism.

8.8 Recommendations and future considerations

There is similarity in the use of different forage across various beekeeping practices in respective provinces. Although some forage sources (i.e. Eucalyptus and agricultural crops) are more favoured than others, this does not make them less important forage sources for beekeeping practices. Of importance is the period at which respective forage sources become available and beekeepers rely on land owners to grant them access to forage. The areas themselves present their own set of challenges (e.g. competition with other beekeepers or hive theft and vandalism). Ultimately, beekeepers need to compete and secure good forage for their hives to be able to make a living from hive based products, and growers require pollination services from managed hives.

Beekeepers do not own much land, if any, and have limited capital for forage planting (de Lange *et al*. 2013). At the same time, growers are happy prepared to pay for pollination services for the given period with little to no interest of how the honey bees fare for the rest of the year. I argue that maintaining colonies throughout the year is equally a grower's responsibility as much as it is of beekeepers. Growers can assist in several ways: 1) maintain natural areas around their farms for bee forage; 2) allowing beekeepers to access forage on their farms free of charge as a form of public good; 3) set aside a portion of land on their property for bee forage planting; 4) plant supplementary crops that are good bee forage were necessary; 5) include the protection of hives against vandalism and theft in their farm security measures, and 6) agree to higher pollination fees as they benefit from the pollination that improves their crop quality and quantity (therefore higher revue and export opportunities), and this will also help beekeepers establish their own forage sites.

The responsibility of securing forage resources for honey bees, and other pollinators, also extends to various agricultural industries (and their respective associations), conservation agencies, governmental institutions and the general public. These institutions need to acknowledge the importance and contribution of managed honey bees in the agricultural sector and the economy at large. Some of these aspects and information has been made public and reiterated at several platforms through the Global Pollination Project and Honey Bee Forage Project (both administered by the South African National Biodiversity Institute - SANBI) for duration of this project. This was done in a form of curriculum material, case studies, booklets, presentations, fact sheets and media releases (see http://www.sanbi.org/biodiversity-science/state-biodiversity/applied-biodiversity-research/global-pollination-honeybee-fo).

Hereafter, these institutions (and concerned parties) must contribute jointly in ensuring the health and continued services provided by managed honey bees. Such efforts could include: 1) formulation of an integrated landscape management policy that will accommodate and facilitate the securing of bee forage, both for exotic and indigenous sources; 2) putting in place measures that will protect areas of important and accessible forage (legislation); 3) exploring the feasibility of allowing managed honey bees to access forage in conservation and protected areas; 4) developing stewardship programmes that will encourage the planting of bee friendly plants on previously disturbed land among communities and growers; 5) by establishing forage corridors, bee friendly tree lanes and urban parks; and finally 6) setting up funding for applied research on honey bees.

Some key practical solutions towards well run beekeeping operations, securing and promoting forage in safe areas for better pollination services would be to:

- Beekeeper associations have to be well structured and managed to allow for a harmonious work ethic and representation of all beekeepers as well as beekeeper issues;

- Beekeeping research needs to be given the much needed attention and funding to address pests, diseases and the lack of local literature on various topics;
- Each province has to acknowledge that it has different forage, pollination and apiary site security needs. Therefore, an in-depth provincial strategy should be developed to assist addressing each of these aspects;
- Different bee forage plants needs to be promoted and planted to support the different beekeeping practices where possible;
- Pollination requirements data for different crops is insufficient or non-existent. It is necessary that beekeeper and farmer associations develop a mechanism of collating data that will allow better assessment and projection for pollination supply and demand;
- The study showed beekeepers to depend heavily on swarm trapping to replenish their colonies. However, this practice is reliant on forage availability and wild swarm populations. This practice is still not fully understood and could possibly have landscape management and sustainable harvesting implications. It therefore recommended that this aspect be explored further looking at the two honey bee races, their genetic pools, wild population estimates and the movement of trapped swarm within the province and across provincial boarders; and
- Hive theft and vandalism also needs an in-depth assessment and annual monitoring to establish its full impact on beekeeping activities. Perhaps legislative measures should also be considered in dealing harshly with the perpetrators liable for these acts.

Securing good forage for honey bees to ensure pollination services is as important as combating diseases and pests that threaten bee populations. In terms of who has to pay, and for what, the trade-offs and benefits needs to weighed carefully relevant institutions and the general public. In reality, beekeepers need assistance (from aforementioned institutions) in maintaining hives to continue providing affordable pollination services. At the same time, our diverse diet and social welfare depends on the products that require pollination (Allsopp *et al*. 2008; Gallai *et al*. 2009; de Lange *et al*. 2013). Furthermore, our economy and export markets thrive on various products and crops dependent of pollination.

In conclusion, this study for the first time captures important national forage use information for the South African beekeeping industry and government that now serves as a baseline for all future research. Before these data on various beekeeping dynamics nationally can be thoroughly and comprehensively understood and unpacked, at provincial levels other beekeeping needs (e.g. marketing of products and research into queen breeding practices/techniques) still require broader attention and assessment. Future research could include, but not be limited to, case studies on: 1) forage use patterns relative to nectar and pollen quality among important forage species (e.g. new cultivars have been introduced for the forestry industry [Eucalyptus species] and the pollen protein and nectar sugar concentration for these species is mostly unknown); 2) updating changing flowering times for most plants (e.g. crop planting times has changed rapidly over the years); 3) assessing the trade-offs between exotic and indigenous bee forage for economic and management justification (as shown by Hutton-Squire 2014); and 4) investigation the current and future implications of pests affecting the nectar and pollen production of various bee plants, but especially Eucalyptus species. The trapping of wild swarms, as well as hive theft and vandalism, are important aspects to consider in future research involving bee forage use as they advocate for key landscape management and conservation practices.

8.9 References

Aizen, M.A. and Harder, L.D. 2009. The global stock of domesticated honey bees is growing slower than agricultural demand for pollination. *Current Biology* 19: 915-918.

Alaux, C., Ducloz, F., Crauser, D. and Le Conte, Y. 2010. Diet effects on honey bee immunocompetence. *Biology Letters* 6: 562-565.

Al-Ghamdi, A., Adgaba, N., Getachew, A. and Tadesse, Y. 2014. New approach for determination of an optimum honey bee colony's carrying capacity based on productivity and nectar secretion potential of bee forage species. *Saudi Journal of Biological Sciences* (2014). http://dx.doi.org/10.1016/j.sjbs.2014.09.020.

Allsopp, M.H. and Cherry, M. 2004. An assessment of the impact on the Bee and Agricultural industries in the Western Cape of the clearing of certain Eucalyptus species using questionnaire survey data. Pretoria (South Africa): National Government of the Republic of South Africa, Department of Water Affairs, Internal Final Report.

Allsopp, M.H. 2006. Analysis of Varroa destructor infestation of Southern African honey bee populations. MSc Dissertation, University of Pretoria, Pretoria.

Allsopp, M.H., de Lange, W.J. and Veldtman, R. 2008. Valuing Insect Pollination Services with Cost of Replacement. *PLoS ONE* 3(9): e3128. doi:10.1371/journal.pone.0003128.

Allsopp, M.H. and Veldtman, R. 2013. The price of being important: the effective management of honey bees as a critical ecosystem service. South African Bee Journal 83(4):160-165.

Attridge, A.J. 1923. Beekeeping in South Africa. The Speciality Press of South Africa, Ltd. Cape Town, South Africa.

Babbie, E.R. and Mouton, J. 2001. The Practice of Social Research. Oxford University Press Inc, New York.

Beekman, M. and Ratnieks, F.L.W. 2000. Long-Range Foraging by the Honey-Bee, *Apis mellifera* L. *Functional Ecology* 14(4): 490-496.

Beekman, M., Sumpter, D.J.T., Seraphides, N. and Ratnieks, F.L.W. 2004. Comparing foraging behaviour of small and large honey-bee colonies by decoding waggle dances made by foragers. *Functional Ecology* 18: 829-835.

Beekman, M., Allsopp, M. H., Wossler, T. C., Oldroyd, B. P. 2008. Factors affecting the dynamics of the honey bee (*Apis mellifera*) hybrid zone of South Africa. *Heredity* 100: 13-18.

Begg, K. and Begg, C. 2002. The conflict between beekeepers and honey badgers in South Africa: A Western Cape perspective. The Open Country N0 4 (Summer 2002): 25-36.

Begg, K. and Allsopp, M.H. 2001. Practical solutions to the beekeeper and honey badger conflict. *South African Bee Journal* 73(3): 135-138.

Breeze, T., Vaissière, B.E., Bommarco, R., Petanidou, T., Seraphides, N., Kozák, L., *et al*. 2014. Agricultural policies exacerbate honey bee pollination service supply-demand mismatches across Europe. *PLoS One* 9(1): e82996. doi:10.1371/journal.pone.0082996

Brodschneider, R. and Crailsheim, K. 2010. Nutrition and health in honey bees. *Apidologie* 41: 278-294.

Bryman, R. 2012. Social Research Methods, 4th Edition. Oxford University Press Inc, New York.

Calderone, N.W. 2012. Insect pollinated crops, insect pollinators and US agriculture: Trend analysis of aggregate data for the period 1992-2009. PLos ONE 7(5): e37235. doi: 10.1371/journal.pone.0037235.

CAPA BEES. 2008-2014. Annual colony loss reports: Retrieved 13 August 2014. Retrieved from: http://www.capabees.com/2014/07/24/capa-statement-on-honey-bees/

Chauzat, M. P., Carpentier, P., Martel, A. C., Bougeard, S., Cougoule, N., Porta, P., Lachaize, J., Madec, F., Aubert, M., Faucon, J. P. 2009. Influence of pesticide residues on honey bee (Hymenoptera: Apidea) colony health in France. *Environmental Entomology* 38: 514-523.

Clark, P. 2012. Tales of an African beekeeper: reflections on bees and beekeeping. Charleston, SC. USA.

Conradie, B. and Nortjé, B. 2008. Survey of beekeeping in South Africa. Centre for Social Science Research. Social Surveys Unit. CSSR Working Paper No. 221.

de Lange, W. J., Veldtman, R. and Allsopp, M. H. 2013. Valuation of pollinator forage services provided by *Eucalyptus cladocalyx*. *Journal of Environmental Management* 125: 12-18.

Du Preez, F.M. 2010. A history of bees and beekeeping in South Africa. Office 444 Govan Mbeki Avenue, Port Elizabeth, South Africa.

Eaden, J., Mayberry, M.K. and Mayberry, J.F. 1999. Questionnaires: the use and abuse of social survey methods in medical research. *Postgraduate Medical Journal* 75 (885): 397-400.

Fletcher, D.J.C. and Johannsmeier, M.F. 1978. The status of beekeeping in South Africa. *South African Bee Journal* 50: 5-20.

Garibaldi, L.A., Steffan-Dewenter, I., Winfree, R., Aizen, M.A., Bommarco, R., Cunningham, S.A., et al. 2013. Wild pollinators enhance fruit set of crops regardless of honey-bee abundance. Science 339 (6127): 1608-1611. DOI: 10.1126/science.1230200.

Fürst, M.A., McMahon, D.P., Osborne, J.L., Paxton, R.J. and Brown, M.J.F. 2014. Disease association between honeybbes and bumblebees as a threat to wild pollinators. *Nature* 506: 364-366.

Hall, A. 2010. Beekeepers use tracking systems as hive thefts rise. Retrieved 03 November 2014. Retrieved from:

http://www.telegraph.co.uk/news/worldnews/europe/germany/7771634/Beekeepers-use-tracking-systems-as-hive-thefts-rise.html

Hepburn, H.R. and Radloff, S.E. 1998. Honey bees of Africa. Springer, New York, USA.

Hepburn, H. R. & Radloff, S. E. 2002. *Apis mellifera capensis*: an essay on the subspecific classification of honey bees. *Apidologie* 33: 105–127.

Hutton-Squire, J.P. 2014. Historical Relationship of the Honey bee (*Apis mellifera*) and its forage; and the current state of Beekeeping within South Africa. MSc Dissertation, University of Stellenbosch, Stellenbosch.

Johannsmeier, M.F. 2001. Beekeeping in South Africa. Plant Protection Handbook No. 14, Agricultural Research Council, Pretoria.

Johannsmeier, M. F. and Mostert, A. J. N. 2001. South African nectar and pollen flora. In: Beekeeping in South Africa, 3rd edition. Plant Protection Research Institute, Handbook No. 14. Agricultural Research Council, Pretoria.

Johannsmeier, M.F. 2005. BEEPLANTS of the South-Western Cape. Nectar and pollen sources of honey bees (revised and expanded). Plant Protection Research Institute Handbook No. 17, Agricultural Research Council, Pretoria.

Johannsmeier, M. F. 2007. Notes on trees as beeplants in South Africa. *South African Bee Journal* 79: 59-64.

Klein, A.M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I, Cunningham, S.A., Kremen, C. and Tscharntke, T. 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society* 274: 303-313.

Kremen, C., Williams, C. N., Aizen, M. A., Gemmill-Herren, B., LeBuhn, G., Minckley, R., Packer, L., *et al*. 2007. Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. *Ecology Letters* 10, 299-314.

Levy, S. 2011. What's best for bees. *Nature* 479: 164-165.

Melin, A., Rouget, M., Midgley, J.J. and Donaldson, J.S. 2014. Pollination ecosystem services in South African agricultural systems. South African Journal of Science 110(11/12): 1-9.

Morse, R.A. and Calderone, N.W. 2000. The value of honey bees as pollinators of U.S. crops in 2000. *Bee Culture* 128: 1-14.

Mouton, M. 2011. Significance of Direct and Indirect Pollination Ecosystem Services to the Apple Industry in the Western Cape of South Africa. MSc Dissertation, Stellenbosch University, Stellenbosch.

NAMAC Report. 2008. 3rd Draft Report. A section 7 committee investigation. The South African Beekeeping Industry. Pretoria, South Africa.

Pirk, C.W.W., Human, H., Crew, R.M. and vanEngelsdorp, D. 2014. A survey of managed honey bee colony losses in the Republic of South Africa – 2009 to 2011. *Journal of Apicultural Research* 53(1): 35-42.

Potts, S.G, Biesmeijer, J.C., Bommarco, R., Felicioli, A., Fischer, M., *et al*. 2011. Developing European conservation and mitigation tools for pollination services: approaches of the STEP (Status and Trends of European Pollinators) project. *Journal of Apicultural Research* 50(2): 152-164.

SANBI 2015. Gum & Bees: A road map for landowners in South Africa. SANBI, Kirstenbosch, Cape Town.

Schehle, A. 1996. Die hidige stand van die Suid-Afrikaanse bye-industrie. (The present status of the South African bee industry). South African Bee Journal 68(5): 137-140.

Schmidt, L. S., Schmidt, J. O., Rao, H., Wang, W., Ligen, X. 1995. Feeding preference and survival of young worker honey bees (Hymenoptera: Apidae) fed rape, sesame and sunflower pollen. *Journal of Economic Entomology* 88: 1591-1595.

Schneider, S.S. and McNally, L.C. 1993. Spatial foraging patterns and colony energy status in the African honey bee, *Apis mellifera scutellata*. *Journal of Insect Behaviour* 6: 195-210.

Smith, K.M., Loh, E.H., Rostal, M.K., Zambrana-Torrelio, C.M., Mendiola, L. Daszak, P. Pathogens, pests, and economics: Drivers of honey bee colony declines and losses. *EcoHealth* 10: 434-445.

Steffan-Dewenter, I. & Westphal, C. 2008. The interplay of pollinator diversity, pollination services and landscape change. *Journal of Applied Ecology* 45: 737–741.

van der Zee, R., Brodschneider, R., Brusbardis, V., Charrière, J-D., Chlebo, R., Coffey, M.F., Dahle, B., Drazi, M.M., Kauko, L., Kretavicius, J., Kristiasen, P., Mutinelli, F., Otten, C., Peterson, M., Raudmets, A., Santrac, V., Seppälä, A., Soroker, V., Topolska, G., Flemming, V. and Gray, A. 2014. Results of international standardised beekper surveys of colony losses for winter 2012-2013: analysis of winter loss rates and mixed effects modelling of risk factors for winter loss. *Journal of Apicultural Research* 53(1): 19-34.

vanEngelsdorp, D. and Meixner, M.D. 2010. A historical review of managed honey bee populations in Europe and the United States and the factors that may affect them. *Journal of Invertebrate Pathology* 103: 580-595.

Visscher, P.K. and Seeley, T.D. 1982. Foraging strategy of honey bee colonies in a temperate deciduous forest. *Ecology* 63: 1790-1801.

Zayed, A. 2009. Bee genetics and conservation *Apidologie* 40, 237-262

Zwaan, T.C.M. 2013. Exploring factors that contribute to sport participation among boys in the middle childhood phase. MSc Dissertation, University of South Africa, South Africa.

Appendix A: Forage use survey questionnaire

National census (survey) to document and assess the forage resources of managed honeybees in South Africa, an initiative of the South African National Biodiversity Institute's Honeybee Forage Project

Section A: Personal and contact details

Please provide the following information in the fields below:

Beekeeper name: ______________________ Contacts: Tel/cell number: ______________

E-mail address: ________________________ Nearest town: ________________________

Years of beekeeping experience: _______ Number of colonies? _____________

Section B: Pollination services

Please indicate the percentage (%) of your colonies used for commercial (paid) pollination? _____________

Indicate the crop type (s) that you pollinate, as a percentage (%): [please ensure that the % for the crop type(s) you fill in adds up to 100%]

Crop type(s):	**%**
Berries	
Deciduous fruit	
Melons	
Nuts	
Oil seeds	
Subtropical fruit	
Vegetable seeds	
Vegetables	
Other (please specify)	
Total	**100%**

Section C: Colony loss/replenishment

What percentage (%) of your colonies do you lose/replace annually (on average)? _________

How do you replace the lost colonies? (please ensure that the % for the categories you fill in adds up to 100%)

Method of colony replacement:	**%**
New colonies (bought)	
Hive splitting	
Swarm trapping	
Removals of problem colonies	
Total	**100%**

Section D: Opinion questions

Please give your opinion on the following questions:

1. How would you like your industry/profession to be recognised / considered? (Mark with a **X**)

   ☐ Beekeepers ☐ Honeybee Service Providers

2. How would you rate the quality of beekeepers in South Africa? (Mark with a **X**):

   ☐ Poor ☐ Satisfactory ☐ Good

3. Briefly motivate your choice for the above answer.

   ____
   ____
   ____
   ____

4. How would you rate the state of beekeeper organizations in South Africa? (Mark with a **X**):

   ☐ Poor ☐ Satisfactory ☐ Good

5. Briefly motivate your choice for the above answer.

   ____
   ____
   ____
   ____

6. Do you think the South African Government is offering adequate support (if any) to the beekeeping industry? **YES/NO**: __________

   IF NO, how would you like them to get involved in supporting the industry?

   ____
   ____
   ____
   ____
   ____
   ____

7. Do you find it easy to access information (i.e. research papers, technical developments) that you feel are of importance for your industry/organisation to be successful? **YES/NO**:___________

8. In your opinion, what are the most important threats facing your industry/organization? Please specify below (e.g. importation of honey; loss of forage; vandalism).

Section E: Forage type and use

Please complete the table as thoroughly as possible. For YOUR honeybee colonies, indicate the value (as a percentage of your total forage resources) for each FORAGE TYPE in terms of honey produced (HONEY CROP), preparing colonies for commercial pollination (POLLINATION), sustaining colonies for the entire year (COLONY BUILD-UP), and the trapping of swarms (SWARM TRAPPING). The percentages for each category should add up to 100 %. **MONTH**(s) of year that the forage type used should be indicated by **1 (Jan) to 12 (Dec)** and **LOCATION** should indicate the nearest FOUR (or less) **TOWNS** to your apiary sites using that forage type. Note that a regional veldtype may be used to indicate forage source, if individual forage species are not known (e.g. suburban gardens; West Coast fynbos).

	FORAGE TYPE	FORAGE USE								
#	Common & Scientific Name	Honey Crop (%)	Pollination (%)	Colony build-up (%)	Swarm trapping (%)	Month	Location - closest town(s)			
	Eucalyptus									
1	River Red Gum (E. camaldulensis)									
2	Sugar Gum (E. cladocalyx)									
3	Karri Gum(E. diversicolor)									
4	Saligna Gum (E. grandis)									
5	Black Ironbark Gum (E. sideroxylon)									
6	Grey Ironbark Gum (E. paniculata)									
7	Yellow Box Gum (E. melliodora)									
8	Tuart Gum (E. gomphocephala)									
9	Red Flowering Gum (E. ficifolia)									
10	Spider Gum (E. conferruminata)									
11	Spotted Gum (E. maculata)									
12	Manna Gum (E. viminalis)									
13	Forest Red Gum (E. tereticornis)									
	Crop plants									
14	Apple (Malus domestica/sylvestris)									
15	Mango (Mangifera indica)									
16	Onion (Allium cepa)									
17	Sunflower (Helianthus annuus)									
18	Macadamia (Macadamia integrifolia)									
19	Lucerne (Medicago sativa)									
20	Litchi (Litchi chinesis)									
21	Citrus (Citrus spp.)									
22	Canola (Brassica napus var. oleifera)									
23	Grape (Vitis vinifera)									
24	Guava (Psidium spp.)									
25	Raspberry (Rubus spp.)									
26	Sugar-cane (Saccharum officinarum)									
27	Avocado (Persea americana)									
	Trees species									
28	Common hook thorn (Acacia caffra)									
29	Sweet thorn (Acacia karroo)									
30	Hook thorn (Acacia mellifera)									

31	Bergaalwyn (Aloe marlothii)									
32	Karee (Rhus lancea)									
33	Bushwillows (Combretum spp.)									
34	Bushveld boekenhout (Faurea saligna)									
35	Buffalo thorn (Ziziphus mucronata)									
		Honey Crop (%)	**Pollination (%)**	**Colony build-up (%)**	**Swarm trapping (%)**	**Month**	**Location - closest town(s)**			
36	Wild Olive (Olea europaea subsp. africana)									
37	Brazilian Pepper (Schinus terebinthifolius)									
38	Australian Myrtle (Myrtaceae spp.)									
39	Mesquite/Vals Kameel (Prosopis spp.)									
	Shrubs; succulents; herbs									
40	Aloe greatheadii subsp davyana									
41	Kanniedood (Aloe grandidentata)									
42	Wild asparagus (Asparagus spp.)									
43	Guarris (Euclea spp.)									
44	Erica spp.									
45	Buckweed (Isoglossa eckloniana)									
46	Mesems (Mesembryanthemaceae)									
47	Cat thorn (Scotia myrtina)									
48	Buchu spp.									
49	Protea spp.									
50	Tolbos (Brunsvigia bosmaniae)									
51	Wasbossie (Morella cordifolia)									
52	Skilpadsbos spp.									
	Weeds									
53	Echium/bloublom (E. plantagineum)									
54	False dandelion (Hypochoeris radicata)									
55	Plantain/ribwort(Plantago lanceolata)									
56	Wild radish/ramnas (Raphanus raphanistrum)									
57	Winter weed (Senecio apiifolius)									
58	Cosmos (Bidens formosa)									
	Regional Generic									
59	Suburban gardens									
60	Indigenous forest									
61	West Coast Fynbos / Strandveld									
62	South Cape Strandveld									
63	Mountain Fynbos									
63	Karoo									
64	Bushveld									
	Other (species or any category; please specify)									

	TOTAL:	**100%**	**100%**	**100%**	**100%**					

Appendix B: Hive Theft and Vandalism Questionnaire Survey

Survey to determine the impact of Theft and Vandalism on the South Africa Beekeeping Industry.

Section A: General Information

1. Beekeepers Name:
2. Postal Address:
3. Contact Details:
4. Years of Beekeeping experience:
5. How many hives do you presently have:

6. Where are your hives situated? Please indicate all your colonies, relative to the nearest town.

Nearest Town	No of Colonies

Nearest Town	No of Colonies

7. What percentage of your colonies are used in commercial pollination? ______________________

Section B: Information regarding hive destruction

8. Please estimate your ANNUAL losses, measured in numbers of colonies, for each of the following categories:
To HIVE THEFT (removal of whole hive, colony = bees and product = honey):

To HONEY THEFT A (removal of honey but bees and hive remain):
To HONEY THEFT B (removal of honey, and only hive remains – bees lost):
To VANDALISM (destruction of whole hive, bees and honey):

9. Please state the area (closest town) where hive losses have occurred IN THE PAST 5 YEARS, and the category of losses:

Nearest Town	Total Losses	Hive Losses (number of colonies)			
		Hive Theft	Honey Theft A	Honey Theft B	Vandalism

10. Estimate your ANNUAL losses relative to the landscape where colonies are kept (in numbers of colonies):

Suburban & Urban		Natural vegetation	
Agricultural land		During commercial pollination	

11. Estimate your ANNUAL losses relative to how visible the apiary site is (in number of colonies):

High visibility		Medium Visibility		Low Visibility	

12. How many apiary sites have you abandoned in the last 5 years as a DIRECT result of theft or vandalism? __________

13. Are there any regions where you previously kept bees, but no longer keep bees, as a direct result of vandalism or theft?

Region	Number of colonies previously kept	Region	Number of colonies previously kept

14. Estimate the percentage change in the number of colonies you keep as a result of vandalism and theft over the past 5 years? ________

15. What measures do you take to limit theft, vandalism or damage to hives? Please describe below.

____

____

____

16. What are your estimated ANNUAL DIRECT losses due to theft, vandalism or damage? Please answer in Rands.

____

17. What are your estimated ANNUAL ADDITIONAL costs in protecting/preventing theft, vandalism or damage? That is: fences or chains or locks or enclosures or straps, as well as petrol and costs for additional patrols, and costs for additional labour etc. All additional costs except your own time. Please answer in Rands. ___________________

18. What is your estimated additional time spent PER MONTH on protecting/preventing theft, vandalism or damage? (in hours) _______

Section C: General Opinion Questions

19. Who do you believe is responsible for your theft, vandalism or damage? Indicate with a X.

Other beekeepers		People trained as beekeepers		Farm workers		Youngsters		Others - specify	

20. What percentage of your losses do you report to the police? ___________________________

21. Please describe the outcome of your report to the police. IE; do they investigate / ignore / solve the case?

____

____

22. Do you believe theft, vandalism and damage has gotten worse in the last 5 years? Yes ________ No ___________

23. To what extent has it gotten worse in the past 5 years? (percentage) _____________________

24. How much would you be willing to pay for a device, which better protects your colonies? (Rands, per colony) _____________

25. How much extra time, per colony, would you be willing to spend operating a security device when opening and closing each hive? (in minutes) _________________________

Appendix C: Forage categories, types and forage sources as well as their respective flowering periods (in months)

	Main Forage Category	Sub Forage Category	Scientific Name	Common Name	Flowering Period
Eastern Cape *(Beekeeper home province. Some species may not occur here, but beekeepers are moving hives to those species from this province.)*	**Exotic forage**	**Forestry (Eucalyptus) includes formal plantations and other stands**	*Eucalyptus grandis* *	Saligna gum	May-Jul
			Eucalyptus cladocalyx *	Sugar gum	Dec-Feb
			Eucalyptus conferruminata *	Spider gum	Aug-Sep
			Eucalyptus diversicolor *	Karri gum	Feb-Apr
			Eucalyptus / Corymbia ficifolia	Red flowering gum	Jun-Jul
			Eucalyptus sideroxylon	Black ironbark gum	Aug-Oct
		Agricultural crops	*Allium cepa*	Onion	Oct-Dec
			Citrus spp.	Citrus	Sep-Nov
			Daucus carota	Carrot	Nov-Dec
			Medicago sativa	Lusern/Lucerne	Sep-Mar
			Malus domestica	Apple	Oct-Nov
			Persea americana	Avocado	Aug-Oct
		Suburban plantings	*Phytolacca dioica* *	Ombú	Oct-Dec
			Schinus terebinthifolius *	Brazillian pepper	Nov-Apr
				Suburban gardens	Sep-Jan
		Weeds	*Raphanus raphanistrum*	Wild radish	Apr-Aug
	Indigenous / Natural Forage	**Indigenous genera**	*Acacia / Senegalia mellifera* ^	Hook thorn	Sep-Dec
			Acacia caffra / Senegalia caffra ^	Common hook thorn	Oct-Mar
			Acacia karroo / Vachellia karroo ^	Sweet thorn	Sep-Mar
			Aloe ferox	Red aloe	Jul-Aug
			Erica spp.	Erica spp.	Jan-Dec
			Euclea spp.	Guarris	May-Sep
			Juncus spp.	Rush	May-Dec
			Mesembs	Mesembs	Jan-Dec

			Olea europaea subsp. cuspidata	Wild olive	Jan-Dec
			Protea spp.	Protea spp.	Jan-Dec
			Salix mucronata	Cape silver willow	Aug-Oct
			Scutia myrtina	Cat thorn	Dec
			Searsia lancea	Karee	Dec-Apr
		Vegetation units		Eastern Cape Thicket	Jan-Dec
				Indigenous Forest	Jan-Dec
				Coastal fynbos	Jan-Dec
				Mountain Fynbos	Dec-Apr
				Karoo	Jan-Dec
				Bushveld	Jan-Dec
	Exotic forage	**Forestry (Eucalyptus) includes formal plantations and other stands**	*Eucalyptus paniculata*	Grey ironbark gum	Sep-Mar
			Eucalyptus / Corymbia ficifolia	Red flowering gum	Dec-Feb
			Eucalyptus sideroxylon	Black ironbark gum	Aug-Mar
		Agricultural crops	*Medicago sativa*	Lusern/Lucerne	Nov-Mar
		Suburban plantings		Suburban gardens	Aug-Oct
		Weeds	*Echium plantagineum*	Echium/Bloublom	Aug-Nov
			Bidens formosa	Cosmos	Mar-May
			Hypochaeris radicata	False dandelion	Aug-Oct
			Plantago lanceolata	Plantain	Aug-Oct
			Raphanus raphanistrum	Wild radish	Apr-Dec
	Indigenous/Natural Forage	**Indigenous genera**	*Acacia / Senegalia mellifera* ^	Hook thorn	Oct-Jan
			Acacia caffra / Senegalia caffra ^	Common hook thorn	Oct-Jan
			Acacia karroo / Vachellia karroo ^	Sweet thorn	Oct-Jan
			Searsia lancea	Karee	Apr-May
			Senecio apiifolius	Winter weed	May-Aug
		Vegetation units		Karoo	Aug-Mar
Gauteng Free State*(Beekeeper home province.)* *(Beekeep er home*	**Exotic Forage**	**Forestry (Eucalyptus) includes formal plantations and other stands**	*Eucalyptus melliodora*	Yellow box gum	Oct-Feb
			Eucalyptus camaldulensis *	River red gum	Sep-Mar

			Eucalyptus cladocalyx *	Sugar gum	Oct-Dec
			Eucalyptus / Corymbia ficifolia	Red flowering gum	Jun-Jan
			Eucalyptus grandis *	Saligna gum	Oct-Feb
			Eucalyptus paniculata	Grey ironbark gum	Aug-Feb
			Eucalyptus sideroxylon	Black ironbark gum	Feb-Oct
			Eucalyptus tereticornis *	Forest red gum	May-Oct
			Eucalyptus viminalis	Manna gum	Mar-Jun
		Agricultural crops	*Citrus spp.*	Citrus	May-Sep
			Helianthus annuus	Sunflower	Jan-Mar
			Litchi spp.	Litchi	Aug
			Macadamia spp.	Macadamia	Oct
			Medicago sativa	Lusern/Lucerne	Sep-Mar
			Magnifera indica	Mango	Aug
			Passiflora edulis	Granadilla	Aug-Apr
			Persea americana	Avocado	Oct-Dec
			Phaseolus vulgaris	Kidney beans	Jan-Mar
			Rubus idaeus	Raspberry	Oct-Feb
			Saccharum spp.	Suger-cane	Dec-May
			Vaccinium spp.	Blueberry	Jun-Dec
		Suburban plantings	*Jacaranda mimosifolia* *	Jacaranda	Aug-Nov
			Schinus terebinthifolius *	Brazillian pepper	Nov-Mar
				Suburban gardens	Sep-Apr
		Weeds	*Acacia decurrens* *	Green wattle	Jul-Sep
			Bidens formosa	Cosmos	Jan-May
			Bidens pilosa	Black jack	Feb-Apr
			Hypochaeris radicata	False dandelion	Feb-Apr
			Prosopis spp. *	Prosopis spp.	Sep-Oct
			Tagetes minuta	Khakhi bush	Oct-Apr
Gauteng	**Indigenous / Natural Forage**	**Indigenous genera**	*Acacia / Senegalia mellifera* ^	Hook thorn	Oct-Jan
			Acacia caffra / Senegalia caffra ^	Common hook thorn	Sep-Jan

KwaZulu-Natal *(Beekeeper home province. Some species may not occur here.)*			*Acacia / Senegalia galpinii*	Monkey thorn	Sep-Jan
			Acacia karroo / Vachellia karroo ^	Sweet thorn	Oct-Jan
			Agathosma spp.	Buchu	Dec
			Aloe grandidentata	Kanniedood	May-Jul
			Aloe greatheadii subsp davyana	Spotted aloe	Jun-Sep
			Aloe marlothii	Mountain aloe	May-Jul
			Asparagus spp. ^	Wild asparagus	Sep-Oct
			Combretum spp.	Bushwillow	Oct-Jan
			Dombeya rotundifolia	Wild pear	Aug-Sep
			Faurea saligna	Bushveld boekenhout	Nov-Jan
			Protea spp.	Protea spp.	Nov-Jan
			Scutia myrtina	Cat thorn	Nov-Jan
			Searsia lancea	Karee	Feb-Jul
			Senecio apiifolius	Winter weed	Apr-Jul
			Ziziphus mucronata	Buffalo thorn	Oct-Jan
		Vegetation units		Bushveld	Jan-Dec
	Exotic Forage	**Forestry (Eucalyptus) incl plantations and other stands**	*Eucalyptus grandis* *	Saligna gum	Jan-Jul
			Eucalyptus sideroxylon	Black ironbark gum	Aug-Mar
		Agricultural crops	*Allium cepa*	Onion	Mar
			Aspalathus linearis	Rooibos	Oct-Feb
			Brassica napus var. oleifera	Canola	Jun
			Citrus spp.	Citrus	Aug-Nov
			Helianthus annuus	Sunflower	Feb-Mar
			Litchi spp.	Litchi	Sep-Oct
			Macadamia spp.	Macadamia	Aug-Oct
			Persea americana	Avocado	Jul-Nov
			Saccharum spp.	Suger-cane	Nov-Jan
			Vitis vinifera	Grape	Mar
		Suburban plantings		Suburban gardens	Jan-Dec

	Indigenous / Natural Forage	**Indigenous genera**	*Acacia karroo / Vachellia karroo ^*	Sweet thorn	Nov-Jan
			Aloe greatheadii subsp davyana	Spotted aloe	May
			Halleria spp.	Halleria spp.	May-Dec
			Searsia lancea	Karee	Aug-Sep
			Ziziphus mucronata	Buffalo thorn	Oct-Feb
		Vegetation units		Indigenous Forest	Jan-Dec
				Eastern Cape Thicket	Dec-Jan
	Exotic Forage	**Forestry (Eucalyptus) includes formal plantations and other stands**	*Eucalyptus grandis **	Saligna gum	Feb-Aug
			*Eucalyptus diversicolor **	Karri gum	Jan-Apr
			Eucalyptus paniculata	Grey ironbark gum	May-Jun
		Agricultural crops	Citrus spp.	Citrus	May-Jul
			Cucurbita sp.	Pumpkin	Jan-Mar
			Cucurbita sp. (Butternut)	Butternut	Nov-Mar
			Helianthus annuus	Sunflower	Nov-Mar
			Litchi spp.	Litchi	Nov-Mar
			Macadamia spp.	Macadamia	May-Oct
			Magnifera indica	Mango	Aug-Nov
			Persea americana	Avocado	Mar-Apr
			Saccharum spp.	Suger-cane	Feb-Mar
		Suburban plantings		Suburban gardens	Jan-Dec
Limpopo*(Beekeeper home province. Some species may not occur here.)*	**Indigenous / Natural Forage**	**Indigenous genera**	*Acacia / Senegalia mellifera ^*	Hook thorn	Sep-Nov
			Acacia caffra / Senegalia caffra ^	Common hook thorn	Oct-Jan
			Acacia karroo / Vachellia karroo ^	Sweet thorn	Dec-Jan
			Aloe greatheadii subsp davyana	Spotted aloe	Jun-Jul
			Faurea saligna	Bushveld boekenhout	Sep-Nov
			Searsia lancea	Karee	Sep-Nov
		Vegetation units		Indigenous Forest	Sep-Mar
				Bushveld	Sep-Jan
Mp uma lang	**Exotic Forage**	**Forestry (Eucalyptus) includes formal**	*Eucalyptus camaldulensis **	River red gum	Jun-Nov

	plantations and other stands	*Eucalyptus fastigata*	Brown barrel gum	Dec-Jan
		Eucalyptus grandis *	Saligna gum	Feb-Jun
		Eucalyptus sideroxylon	Black ironbark gum	Mar-Aug
	Agricultural crops	*Brassica napus var. oleifera*	Canola	Jul-Aug
		Citrus spp.	Citrus	Aug-Nov
		Helianthus annuus	Sunflower	Feb-Mar
		Litchi spp.	Litchi	Aug-Nov
		Macadamia spp.	Macadamia	Sep-Dec
		Medicago sativa	Lusern/Lucerne	Nov-Mar
		Magnifera indica	Mango	Sep-Nov
		Malus domestica	Apple	Oct-Dec
		Persea americana	Avocado	Sep-Oct
		Phaseolus vulgaris	Kidney beans	Jan-Mar
		Psidium guajava	Guava	Sep-Dec
		Rubus idaeus	Raspberry	Feb-Mar
		Saccharum spp.	Suger-cane	Nov-May
		Vitis vinifera	Grape	Mar
	Suburban plantings		Suburban gardens	Jan-Dec
	Weeds	*Bidens formosa*	Cosmos	Mar-Apr
		Bidens pilosa	Black jack	Feb-Apr
Indigenous / Natural Forage	**Indigenous genera**	*Acacia karroo / Vachellia karroo* ^	Sweet thorn	Dec-Feb
		Aloe greatheadii subsp davyana	Spotted aloe	Jun-Aug
		Aloe marlothii	Mountain aloe	Jun-Aug
		Asparagus spp. ^	Wild asparagus	Sep-Nov
		Combretum spp.	Bushwillow	Jun-Aug
		Dombeya rotundifolia	Wild pear	Jul-Sep
		Euclea natalensis	Natal guarri	Jun-Nov
		Faurea saligna	Bushveld boekenhout	Dec-Feb
		Halleria lucida	Tree fuchsia	Jun-Nov
		Searsia chirindensis	Red currant	Aug-Dec

Northern Cape(*Beekeeper home province. Some species may not occur here.)*			*Searsia lancea*	Karee	Jul-Aug
			Senecio apiifolius	Winter weed	Jun-Aug
			Ziziphus mucronata	Buffalo thorn	Sep-Nov
		Vegetation units		Bushveld	Jan-Dec
				Indigenous Forest	Sep-Nov
	Exotic Forage	**Forestry (Eucalyptus) includes formal plantations and other stands**	*Eucalyptus sideroxylon*	Black ironbark gum	Mar-Aug
			Eucalyptus camaldulensis *	River red gum	Nov
			Eucalyptus melliodora	Yellow box gum	Sep-Oct
		Agricultural crops	*Allium cepa*	Onion	Oct-Nov
			Cucurbita sp.	Pumpkin	Oct-Mar
			Helianthus annuus	Sunflower	Feb-Mar
			Medicago sativa	Lusern/Lucerne	Sep-Mar
		Suburban plantings	*Schinus terebinthifolius* *	Brazillian pepper	Jan-Mar
				Suburban gardens	Nov-Mar
		Weeds	*Hypochaeris radicata*	False dandelion	Aug-Oct
			Prosopis spp. *	Prosopis spp.	Oct-Dec
	Indigenous / Natural Forage	**Indigenous genera**	*Acacia / Senegalia mellifera* ^	Hook thorn	Aug-Oct
			Acacia caffra / Senegalia caffra ^	Common hook thorn	Aug
			Acacia karroo / Vachellia karroo ^	Sweet thorn	Dec-Jan
			Acacia tortilis / Vachellia tortilis ^	Umbrella thorn	Nov-Mar
			Aloe grandidentata	Kanniedood	Jul-Aug
			Aloe marlothii	Mountain aloe	Jun-Sep
			Olea europaea subsp. cuspidata	Wild olive	Jan-Mar
			Searsia lancea	Karee	Feb-Apr
			Senecio apiifolius	Winter weed	May-Aug
			Ziziphus mucronata	Buffalo thorn	Oct-Jan
			Zygophyllum spp.		Jun-Jul
		Vegetation units		Namaqualand & Renosterveld	Jul-Sep
				Karoo	May-Aug

North West(*Beekeeper home province. Some species may not occur here.*)	**Exotic Forage**	**Forestry (Eucalyptus) includes formal plantations and other stands**	*Eucalyptus grandis* *	Saligna gum	Nov-Feb
			Eucalyptus camaldulensis *	River red gum	Sep-Dec
			Eucalyptus melliodora	Yellow box gum	May-Dec
			Eucalyptus paniculata	Grey ironbark gum	Apr-Aug
			Eucalyptus sideroxylon	Black ironbark gum	Mar-Oct
			Eucalyptus tereticornis *	Forest red gum	Sep-Nov
			Eucalyptus viminalis	Manna gum	Nov-Jan
		Agricultural crops	*Cucurbita sp.*	Pumpkin	Dec-Jan
			Macadamia spp.	Macadamia	Jan-Apr
		Suburban plantings		Suburban gardens	Jan-Dec
		Weeds	*Bidens formosa*	Cosmos	Mar-May
			Raphanus raphanistrum	Wild radish	May-Jul
	Indigenous / Natural Forage	**Indigenous genera**	*Acacia / Senegalia mellifera* ^	Hook thorn	Sep-Oct
			Acacia caffra / Senegalia caffra ^	Common hook thorn	Sep-Dec
			Acacia karroo / Vachellia karroo ^	Sweet thorn	Oct-Jan
			Aloe greatheadii subsp davyana	Spotted aloe	Jul-Aug
			Aloe marlothii	Mountain aloe	Jun-Jul
			Searsia lancea	Karee	Apr-Jul
			Ziziphus mucronata	Buffalo thorn	Nov-Jan
		Vegetation units		Bushveld	Sep-Jan
Western Cape(*Beekeeper home province. Some species may not occur here, but beekeepers are moving hives to those*	**Exotic Forage**	**Forestry (Eucalyptus) includes formal plantations and other stands**	*Eucalyptus camaldulensis* *	River red gum	Aug-Jan
			Eucalyptus cladocalyx *	Sugar gum	Dec-Mar
			Eucalyptus conferruminata *	Spider gum.	Sep-Mar
			Eucalyptus diversicolor *	Karri gum	Sep-Apr
			Eucalyptus / Corymbia ficifolia	Red flowering gum	Sep-Apr
			Eucalyptus gomphocephala	Tuart gum	Nov-May
			Eucalyptus grandis *	Saligna gum	Sep-May
			Eucalyptus / Corymbia maculata	Spotted gum	Feb-Jun
			Eucalyptus melliodora	Yellow box gum	Aug-Feb

		Eucalyptus paniculata	Grey ironbark gum	Aug-Oct
		Eucalyptus sideroxylon	Black ironbark gum	Mar-Sep
		Eucalyptus tereticornis *	Forest red gum	Aug-Nov
		Eucalyptus viminalis	Manna gum	Feb-Jun
	Agricultural crops	*Allium cepa*	Onion	Nov-Jan
		Brassica napus var. oleifera	Canola	Jun-Sep
		Brassica sp. (Broccoli)	Broccoli	Apr-Nov
		Brassica sp. (Cabbage)	Cabbage	Jul-Aug
		Brassica sp. (Cauliflower)	Cauliflower	Apr-Nov
		Citrus spp.	Citrus	May-Nov
		Cucurbita sp.	Pumpkin	Dec-Mar
		Daucus carota	Carrot	Nov-Dec
		Helianthus annuus	Sunflower	Jan-Mar
		Macadamia spp.	Macadamia	Aug-Feb
		Medicago sativa	Lusern/Lucerne	Oct-Apr
		Magnifera indica	Mango	Nov-Jan
		Malus domestica	Apple	Sep-Nov
		Prunus spp.	Prune/Plum	Aug-Nov
		Psidium guajava	Guava	Apr-Dec
		Pyrus communis	Pear	Sep-Nov
		Rubus idaeus	Raspberry	Feb-Mar
		Trifolium spp.	Clover	Jul-Sep
		Vicia dasycarpa	Purple vetch	Mar-Apr
		Vitis vinifera	Grape	Dec-Mar
	Suburban plantings	*Quercus robur*	English oak	Sep
		Schinus terebinthifolius *	Brazillian pepper	Oct-May
			Suburban gardens	Jan-Dec
	Weeds	*Echium plantagineum*	Echium/Bloublom	Jul-Dec
		Hypochaeris radicata	False dandelion	Feb-Apr
Western Cape(*Beekee per home*		*Leptospermum laevigatum* *	Coastal Tea Tree	Aug-Sep

		Myoporum tenuifolium *	Manatoka	Sep-Nov
		Prosopis spp. *	Prosopis spp.	Oct-Jan
		Raphanus raphanistrum	Wild radish	May-Oct
Indigenous / Natural Forage	**Indigenous genera**	*Acacia karroo / Vachellia karroo* ^	Sweet thorn	Nov-Jan
		Agathosma spp.	Buchu	Mar-Oct
		Aloe ferox	Red aloe	Jun-Jul
		Aloe marlothii	Mountain aloe	Jul
		Asparagus spp. ^	Wild asparagus	Sep-Oct
		Carpobrotus edulis	Sour fig	Aug-Oct
		Erica spp.	Erica spp.	Apr-Oct
		Euclea spp.	Guarris	Jan
		Euryops Virgineus	Honey euryops	Nov-Jan
		Isoglossa eckloniana	Buckweed	Mar-Jul
		Mesembs	Mesembs	Aug-Feb
		Morella cordifolia	Wasbossie	Jan-Feb
		Olea europaea subsp. cuspidata	Wild olive	May-Aug
		Oxalis pes-caprae ^	Buttercup oxalis	Jan-Mar
		Oxalis stricta	Commom yellow woodsorrel	Aug-Oct
		Protea spp.	Protea spp.	May-Dec
		Scutia myrtina	Cat thorn	Mar-Jul
		Searsia lancea	Karee	Oct-May
		Searsia pedulina	White karee	Apr-May
		Watsonia fourcadei	Watsonia fourcadei	Jul-Sep
		Zygophyllum spp.		Mar-Apr
	Vegetation units		Coastal fynbos	Jan-Dec
			Mountain fynbos	Jan-Dec
			Strandveld	Jan-Dec
			Karoo	Jan-Dec
			Indigenous Forest	Jan-Dec
			Namaqualand & Renosterveld	Jan-Dec

	Bushveld	May

Appendix D: Grower's questionnaire for planting area and pollination hives data

The supply and demand of managed honeybee colonies for crop pollination in the South African agriculture industry: An initiative of the South African National Biodiversity Institute's Honeybee Forage Project

The past decade has seen major declines in insect pollinators across Europe and the United States of America, including unprecedented losses in managed honeybee colonies. This has raised concerns about the continued supply of pollination services to the crop production industries requiring intensive and commercial pollination. The unavailability of such pollination services would obviously threaten the viability of these crop production sectors, and ultimately, global food security. Globally, there are currently numerous efforts being made to determine the causes of the honeybee losses, focusing on diseases and pesticides, as well as efforts being made to mitigate the pollination shortages. These efforts focus on improving the forage for honeybees and other pollinators, developing alternative commercial pollinators, and improving on-farm practices to better support pollinators.

While South Africa is fortunate not to have the reported honeybee losses of Europe and the USA, there are reasons to be concerned that our honeybee population is not as healthy as it has been in the past. The recent advent of new honeybee diseases in our population is testament to a population under stress, and beekeepers across the breadth of the country have been reporting unhealthy bees in the past few years. Additionally, honey production has dramatically decreased in South Africa in the past two decades, largely as a result of the loss of suitable honeybee forage resulting from urbanization and development. Increased hive theft and vandalism in some areas of the country have also made beekeeping less viable than was the case in the past.

The **South African National Biodiversity Institute (SANBI)** is presently involved in an initiative to evaluate the current or potential threat posed to agricultural production in South Africa by a loss or limitation of managed honeybee colonies. One aspect of this initiative is to accurately assess the existing density and distribution of managed honeybees in South Africa, and to assess those factors such as bee forage and vandalism that might restrict this density or dictate the distribution. In this regard, SANBI has exhaustively examined the bee forage that beekeepers in all parts of South Africa depend upon in the maintenance of their colonies. The second component that the SANBI initiative is examining is the **DEMAND** for commercial honeybees as a pollination service. It is generally believed that honeybees are important pollinators for approximately 50 insect pollinated commercial crops in South Africa, but data on the usage of honeybees for this service is entirely lacking. It is obvious that only if the true demand and value of honeybees in commercial crop pollination is known, can the threat posed by the potential regional and national shortage of managed honeybee colonies be determined. It is equally obvious that the future development of agricultural production that depend on honeybee pollination in South Africa should be informed by the future availability of sufficient honeybee colonies to pollinate these crops.

To this end, **all crop production sectors in South Africa that utilise managed honeybees for pollination or increased production are being asked to PLEASE assist in determining the national and regional demand for honeybees as commercial pollinators in South Africa.** These data will be of crucial importance in determining the likely severity of pollination shortages in South Africa, and should be of great benefit to Grower organizations in optimising their production and in planning for the future.

The information requested is in the form of **3 Tables** that we are asking each crop production sector to complete. We are aware that not all crop production sectors will have all the information, but we are requesting each sector to complete the tables as fully as possible.

Table 1 asks for the historical, current and projected plantings of the insect pollinated crops in your sector; each sector is provided a list of crops in that sector for which information is sought. That is, the total hectares of each listed crop that was planted in South Africa in 2003, 2008 and 2013, and the projected hectares of each crop in 2018. By means of an example, the Table below indicates these data in the Deciduous Fruit Industry, kindly provided by Hortgro.

Fruit Kind	**Sum of Area (ha)**			
	2003	**2008**	**2013**	**2018**
Appel / Apple	21,812	20,736	22,167	22,389
Appelkoos / Apricot	4,615	3,751	3,230	3,114
Nectarines	1,393	1,890	2,140	2,230
Peer / Pear	12,387	11,425	11,703	11,764
Perske / Peach	1,347	1,379	1,693	1,767
Pruim / Plum	4,493	4,081	4,814	4,997
Grand Total	**46,047**	**43,262**	**45,747**	**46,261**

Table 2 asks for the geographical distribution of the listed insect pollinated crops in your sector in 2013, indicated either as the total numbers of hectares of each crop planted per province (as indicated in the Table prepared for the Deciduous Fruit sector below), or presented as the number of hectares of each crop in a magisterial district, or indicated by the nearest town, or by any other geographical representation.

Agricultural crop	Provincial distribution in hectares (ha) for the year 2013								
	Eastern Cape	Free State	Gauteng	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape
Apple									
Pears									
Prunes/Plums									
Apricots									
Peaches									
Nectarines									

Table 3 asks for information related to the use of honeybee colonies for commercial pollination services in the listed crop types in your sector during 2013, as well as for information on the possible gratuitous pollination of crops as a result of the forage seeking activity of beekeepers. It requests information for each crop type on the numbers of hectares of that crop that are pollinated by commercial bees and the number of hired colonies per hectare that are used; the numbers of colonies per crop type that are introduced without payment by beekeepers; the numbers of hectares that are pollinated by managed but non-commercial honeybee colonies ('own bees'); and the numbers of hectares that are pollinated by non-managed honeybees (see Table below).

Agricultural crop	Commercial pollination		Gratuitous pollination		Farm colonies		Wild pollination
	Hectares planted	*Average hives per hectare	Hectares planted	*Average hives per hectare	Hectares planted	*Average hives per hectare	Hectares planted
Apple							
Pears							
Prunes/Plums							
Apricots							
Peaches							
Nectarines							

Commercial pollination – colonies are introduced specifically as a paid pollination service
Gratuitous pollination – colonies are introduced by beekeepers for honey production
Farm colonies – permanent and managed honeybee colonies are present
Wild pollination – no managed honeybee colonies are present

It is appreciated that most crop production sectors will not have the information requested in Table 3 available, or they may only have a rough estimate of the information available. Should this be the case, it is requested that the sector indicate this absence of information by reporting either **no data available** or **rough estimate only,** together with the information submitted.

It is further suggested, if at all possible, that each crop production sector should begin to gather the information necessary to populate Table 3 from their growers, to determine the dependency of each crop and in each region on honeybee pollination services, by whatever means each sector gathers information from their growers. This information might well prove to be crucial in the near future in assuring that there are sufficient honeybees to pollinate a particular crop type in a particular region, or might provide the necessary motivation for the planting of bee forage in a region, to ensure there are sufficient bees for the pollination of that particular crop. It is further suggested that these data collection should be a continuous exercise, and that the information gathered should be made available for national and regional future planning purposes.

Should you have any questions or queries about the survey, please do not hesitate to contact me on the following: Mobile +27 (0)78 285 2553 Email T.Masehela@sanbi.org.za

You can also get hold of my supervisors, Mike Allsopp (ARC) & Ruan Veldtman (SANBI & Stellenbosch University), on the following email addresses: AllsoppM@agric.za & Veldtman@sun.ac.za

Please submit all surveys (in Excel or Word Doc format) via email at the same email address provided above.

Thank you for taking time out of your busy schedule to complete this survey!

Sincerely,
Tlou Masehela (PhD candidate)
SANBI & Stellenbosch University

Appendix E: Cover letter circulated with the journal, declaring assurance of anonymity to beekeepers.

National census (survey) to document and assess forage resources of managed honeybees in South Africa, an initiative of the South African National Biodiversity Institute's Honeybee Forage Project

South Africa is fortunate to have a vibrant and healthy indigenous honeybee population. Yet managed beekeeping in South Africa is not in a healthy or vibrant condition. In the past 20 years national honey production has declined from approximately 4500 tons per annum to under 2000 tons. Possible reasons for this situation includes the removal of eucalyptus; the increased presence of eucalyptus pests, such as the eucalypt nectar fly; changes in eucalyptus plantation species being planted; increased theft and vandalism rendering sites no longer safe; increased urbanization and loss of habitat; new honeybee pests and diseases; and increasing honey imports making local beekeeping less profitable. Loss of forage is therefore seen as a significant contributor towards the difficulties of sustaining managed honeybee keeping in South Africa. Nationally, beekeepers are becoming more and more concerned about the loss of suitable bee forage, and the difficulties in finding safe and profitable apiary sites. Adequate and suitable bee forage is an obvious prerequisite for a healthy beekeeping industry in South Africa.

South Africa's honeybees rely on both indigenous and exotic (invasive and non-invasive) species, flowering crops, and suburban plants to provide important forage sources to sustain and stimulate colonies throughout the year. These colonies are then used for commercial honey production which is the lifeblood of most beekeepers. On the other hand, honeybees are the most important generalist pollinator in our natural landscapes, and the most important pollinator for approximately 50 insect pollinated commercial crops in South Africa. It is thus of utmost importance for us, as a nation, to ensure that our honeybee populations have all year round adequate supplies of good quality forage.

We, Tlou Masehela and James Hutton-Squire, PhD and MSc research students, respectively, at Stellenbosch University, Department of Conservation Ecology and Entomology and co-investigators of the Honeybee Forage Project (HFP), wish to undertake research leading towards a better understanding of conserving and sustaining important honeybee forage to ensure that the bee forage important to your industry is well looked after. Essential to this research is a strong knowledge and understanding of which forage resources build and sustains your bee colonies and support your honey production year round. ONLY beekeepers know the answers to these questions. By you taking part in the survey, we will be able to collect valuable data needed to further this very important research. For us to succeed we NEED your help!

The Working for Water Programme (WfW) funds the Honeybee Forage Project which is implemented by the South African National Biodiversity Institute (SANBI) and the Agricultural Research Council (ARC). As an organisation they want you to help determine what forage is of importance to you and the beekeeping industry and how to maintain and build-up this forage. We assure you that all the information collected will contribute solely towards our research studies, research papers and reporting of GENERAL findings and generic outputs by the research institutions involved. All information will be considered CONFIDENTIAL and NO individual responses shall be released or published in any form or manner.

Should you have any questions about the survey or the project, please phone, e-mail or sms us. Alternatively, leave us a message and we will gladly respond or return your call if necessary. **Details:** Tlou Masehela: M +27 (0)78 285 2553 E T.Masehela@sanbi.org.za or James Hutton-Squire: M +27 (0)76 647 6902 E jameshs@sun.ac.za.

Please note: The survey can be completed in either English or Afrikaans. Completed electronic versions should be mailed to honeybeeforageproject@gmail.com while hard copies should be posted using the **pre-paid postage envelopes**, to the Tlou Masehela & James Hutton-Squire, Honeybee Forage Project; Applied Biodiversity Research; Kirstenbosch Research Centre; South African National Biodiversity Institute; Private Bag X7; Claremont 7735; Cape Town. To assist you in completing the questionnaire, an example of a completed questionnaire is included.

Thank you for taking time out of your busy schedule to complete this survey.