A review of academically substantiated guidelines for designing honey bee habitat in residential yards

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Abstract of a dissertation submitted in partial fulfilment of the requirements for the Degree of Master of Landscape Architecture.

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Honey bee *Apis mellifera* populations are under threat globally. Honey bees provide important ecosystem services through pollination, honey production and provide a connection to nature. Declines in honey bees will have a negative impact on human populations. This review describes honey bee habitat needs, finding that honey bees are able to thrive in an urban residential environment, if urban yards are designed and managed appropriately. Guidelines are suggested as a tool, translating honey bee research into practical recommendations for both residents and landscape architects. Best practice criteria for guidelines are then established. Existing guidelines are assessed to determine whether suitable guidelines are available. Guidelines found in a systematic literature review offer insufficient recommendations for urban residents to easily take action and enhance honey bee habitat within their yards. Interdisciplinary research will be required to develop guidelines for urban residents and landscape architects to enhance honey bee habitat within their properties to ensure the key ecosystem services honey bees provide are preserved.

Keywords: Honey bees, Apis mellifera, pollinator, habitat, urban, residential, ecosystem services, guidelines, recommendations

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Chapter 1

Introduction

Unexplained losses of honey bee *Apis mellifera* colonies are occurring worldwide at alarming rates (Potts et al., 2016). Despite extensive research efforts there is continued debate regarding the cause and researchers have coined the term Colony Collapse Disorder (CCD) to describe this new and unknown occurrence. Many believe CCD arises from a number of stresses including nutritional stress, pesticide use, pests and parasites (Goulson, Nicholls, Botías, & Rotheray, 2015). CCD continues to threaten the longevity of honey bee populations and the ecological and social services they provide (Potts et al., 2016). At the same time, urban areas continue to expand, exacerbating the stresses placed on honey bees through destruction of important habitats and poor land use and management choices. The need to protect honey bees and their habitat is becoming critical (Baldock et al., 2015). More public engagement and increased education is needed to ensure honey bee habitat is created, enhanced and managed appropriately within both public and private land (Faeth, Bang, & Saari, 2011).

Mwebaze et al. (2018) researched public perception and carried out a cost-benefit analysis highlighting the high value the public placed on honey bees and their services. These results show the need for stakeholders to invest in implementing strategies and policies to help protect pollinators and continue to raise public awareness about honey bees and their beneficial attributes. Residents are increasingly interested in supporting honey bees in their yards, and urban bee keeping is becoming increasingly popular worldwide (Lorenz & Stark, 2015; Perrone & Malfroy, 2014). In New Zealand, a study found that urban gardens are the primary source of food for hobbyist beekeepers' colonies (Brown, Newstrom-Lloyd, Foster, Badger, & McLean, 2018). Research has also highlighted starvation as one of the primary reasons for colony loss in New Zealand, due to the number of colonies continuing to climb at disproportionate rates to food availability from flowers (Brown et al., 2018). Research shows honey bees are able to adapt and potentially thrive in an urban environment, if appropriate land use and management strategies can be implemented (Potts et al., 2016).

Guidelines can be an effective educational tool for converting research into information which can be used in practice (Jerlock, Falk, & Severinsson, 2003). However, studies indicate there is a lack of clear guidelines on how to increase habitat and reverse biodiversity loss in urban areas (Threlfall et al., 2017), and little information is provided in planning documents regarding improvement and monitoring of ecosystem services (Haase et al., 2014; Woodruff & BenDor, 2016). Residential gardens have the capacity to provide a haven for urban honey bees, creating habitat and a stable food supply, however, it is not yet known whether effective guidelines are available to residents to assist them in the design and management of honey bee habitats.

This research investigates whether there are guidelines available to residents for creating and managing honey bee habitat in New Zealand cities. If there are guidelines, it evaluates whether they are effective relative to best guideline development criteria.

1.1 Research Questions

1. What are the habitat needs of honey bees?
2. What are best practice guideline criteria?
3. Are there existing guidelines for supporting honey bees in residential yards?
4. If there are guidelines for this, are they effective relative to best practice guideline criteria and the habitat needs of honey bees?

1.2 Research Objectives

1. To identify the habitat needs of honey bees.
2. To identify what makes best practice guideline criteria.
3. To investigate if there are existing guidelines for supporting honey bees in residential yards.
4. To evaluate existing guidelines for managing honey bees based on the attributes required for best practice guidelines and habitat needs of honey bees.

Chapter 2

Methods

2.1 Research Design

This research determines whether there are Landscape Architectural guidelines for supporting honey bees in residential yards using a systematic literature review. The effectiveness of guidelines in supporting honey bees is evaluated by using the finding from the narrative review identifying the needs of honey bees and guideline attributes determined in a second narrative literature review.

Chart 1. Steps and methods for answering research questions by chapter.

Steps	Methods	Comments
Critically review the literature looking at honey bee status, significance and factors leading to declines and review their habitat requirements.	Narrative review	Chapter 3
Critically review the guideline literature to define what a guideline is and identify best practice attributes of guidelines.	Narrative review	Chapter 4
Determine whether there are existing Landscape Architecture guidelines for supporting honey bees in residential yards and evaluate their effectiveness.	Systematic literature review	Chapter 5
Discuss implications of findings regarding guidelines for honey bees in residential yards, and next steps in their implementation and research in support of honey bees in residential yards. What are the implications for Landscape Architecture, residents and hobbyist beekeepers?	Discuss findings regarding existing and recommended guidelines in context of narrative literature review.	Chapter 6
Summarize conclusions regarding the status, significance and challenges of providing habitat for honey bees to reverse their decline, and the key role played by guidelines. Discuss next steps in honey bee research to further advance guidelines in future.	Reflect on research journey and possible next steps	Chapter 7

Chapter 3

Status of Honey Bees

This chapter builds on a literature review carried out for another class (Appendix B).

3.1 Regulating Ecosystem Services

Honey bees provide pollination which is a key regulating ecosystem service. Regulating services are ecosystem services which ensure the sustainability of resources that support human wellbeing (Simonit & Perrings, 2011). Pollination is a mutually beneficial relationship because honey bees deliver the service of transferring pollen between flowers allowing them to reproduce, and in return, are rewarded with nectar and pollen (Newstrom-Lloyd, 2013). Honey bees pollinate fruit, vegetables and grains required to fulfil human's nutritional needs; declines or extinction of honey bees would have significant adverse effects on the human diet (Genersch, 2010). Globally, insect pollination services are valued at approximately US$215 billion per year (Gallai, Salles, Settele, & Vaissière, 2009). In New Zealand the economic value of pollination services is difficult to quantify (Newstrom-Lloyd, 2013). Honey bees contribute greatly to the agricultural sector in New Zealand because they pollinate both arable crops and nitrogen fixing crops such as clover used for supporting livestock (Newstrom-Lloyd, 2013). Historically in New Zealand pollination of crops has been a natural occurrence because both managed and wild honey bee colonies provided pollination while foraging for food (Newstrom-Lloyd, 2013). The increase in pests and diseases and subsequent decline in wild honey bee colonies means background pollination is no longer sufficient for some commercial crops, opening a market for beekeepers to rent out hives for pollination of agricultural products including kiwifruit and apples (Newstrom-Lloyd, 2013).

Pollination plays a key role in supporting New Zealand's unique ecosystem. The ecosystem is made up of endemic flora and fauna mixed with introduced naturalized species (Newstrom-Lloyd, 2013). Many native plants rely on the pollination services of generalist pollinators such as honey bees in order to reproduce (Lloyd, 1985).

3.2 Provisioning services

Provisioning services are defined as ecosystem services providing a product benefiting humans (Engel, Pagiola, & Wunder, 2008). In New Zealand both hobbyist and commercial beekeepers primarily produce honey (Brown et al., 2018). Honey is considered a provisioning service because it has provided humans with a product of high medical and nutritional value for thousands of years

(Bogdanov, Jurendic, Sieber, & Gallmann, 2008). Recently, the consumption of honey has increased due to its promotion as a natural sweetener (Pasias, Kiriakou, Kaitatzis, Koutelidakis, & Proestos, 2018). The value of honey is influenced by palatability, appearance and medicinal value, this is largely determined by the flower species within foraging distance from the hive. The flowers used to make the honey determine the honey's chemical makeup and influence the flavour and colour (Bogdanov et al., 2008), for example acacia honey is sweeter than rape honey (Bogdanov, Ruoff, & Oddo, 2004).

The medicinal benefits of honey are well documented. It is used in many healthcare products for its antioxidant and antibacterial properties (Bogdanov et al., 2008) which make it useful in the treatment of wounds, burns and infections (Molan, 2001). New Zealand's Manuka Honey is a high value product because of its unique healing qualities; it has been found to inhibit growth of pathogens (Bulman, Tronci, Goswami, Carr, & Russell, 2017) and oral bacteria (Badet & Quero, 2011).

3.3 Cultural Ecosystem Services

Cultural ecosystem services are interactions with nature which help define cultural identity. These may include spiritual benefits, knowledge, educational values, inspiration, aesthetic values, recreational values and a feeling of closeness to nature obtained from connection with the surrounding ecosystems (Millennium Ecosystem Assessment, 2005). Closeness to nature has been found to increase quality of life (Streimikiene, 2015). The value of functioning ecosystems is often taken for granted and given little consideration in urban development (Dorning, Koch, Shoemaker, & Meentemeyer, 2015).

3.4 Threats

Worldwide, honey bee populations are declining. These declines have been attributed to a number of factors including; pesticide use (Di Prisco et al., 2013; Goulson, 2013; Whitehorn, O'connor, Wackers, & Goulson, 2012), habitat loss (Naug, 2009; Winfree, Aguilar, Vázquez, LeBuhn, & Aizen, 2009), introduction of invasive species (Sugiura, Tsuru, & Yamaura, 2013), and pathogens and parasites (Potts et al., 2010; Vanbergen & Insect Pollinators, 2013).

At present, the threats to honey bees in New Zealand are less than the threats to honey bees in Europe and the USA. The current over winter loss rate of honey bee colonies in New Zealand sits at less than 10% (Brown et al., 2018) compared with over winter losses in the USA of over 20% (Lee et al., 2015) and up to 22% in Europe (Van der Zee et al., 2012). The population of honey bees in New Zealand is actually rapidly increasing due to extensive breeding programs which are driven by the high demand for Manuka Honey (Brown et al., 2018). Therefore, the challenge honey bees and beekeepers are facing is not a declining honey bee population but an increase in colony loss

(Neumann & Carreck, 2010). Colony loss is when thriving honey bee colonies become weak and either die or vanish with no obvious cause (Higes et al., 2008).

3.5 Nutritional Stress and Starvation

Nutritional stresses are one of the causes leading to Colony Collapse Disorder (CCD) in Europe and the United States (Alaux, Ducloz, Crauser, & Le Conte, 2010; Vanbergen & Insect Pollinators, 2013; Vaudo, Tooker, Grozinger, & Patch, 2015). Similarly, in New Zealand, starvation is leading to colony loss because the number of managed honey bee colonies is rapidly increasing and good foraging habitat is declining, leading to more competition for food (Brown et al., 2018). The increasing population of honey bees, in conjunction with declining foraging habitat due to land use intensification, is making it harder for worker bees to gather sufficient energy, protein and micronutrients to support their colonies (Newstrom-Lloyd, 2013). Beekeepers are boosting honey bee nutrition by feeding pollen and nectar supplements to the hives however, because there are significant gaps in knowledge regarding the nutritional needs of honey bees, substitutes may not fulfil the nutritional needs of the colony (Newstrom-Lloyd, 2013).

3.6 Pests and Pathogens

Researchers believe pests and pathogens are a leading cause for CCD globally (Genersch, 2010; Meixner, 2010). One of the leading causes of colony loss in New Zealand is Varroa destructor (Brown et al., 2018). It is a ectoparasitic mite which infects honey bees causing colony loss if left untreated (Genersch, 2010). Varroa destructor was introduced to New Zealand and spread though the country in 2000, much later than many other major beekeeping countries (Newtrom-Lloyd, 2013). Domestication of honey bees has now reached a level where colonies are unable to survive without human input. Varroa destructor decimated New Zealand's wild honey bee populations and newly established colonies created from swarming managed hives will not survive unless treated for Varroa destructor (Newstrom-Lloyd, 2013).

American Foul Brood (AFB) is one of the most serious honey bee diseases in New Zealand. The number of cases reported each year is increasing despite programs which are in place to stop the spread of AFB including training programs, regular monitoring and quarantine requirements to burn infected hives (Brown et al., 2018).

3.7 Insecticides

It is generally agreed that exposure to neonicotinoids reduces honey bee health and increases morality rates (Gill, Ramos-Rodriguez, & Raine, 2012; Tsvetkov et al., 2017). However, the severity of the negative effects on honey bees is fiercely debated between environmental and agricultural groups (Godfray et al., 2014). Neonicotinoids are effective insecticides, used for controlling pests in agricultural and horticultural practices worldwide (Godfray et al., 2014; Goulson, 2013). Plants absorb the neonicotinoids which are then transported through the entire plant. Traces can be found in nectar and pollen of treated crops which are ingested by foraging honey bees (Goulson, 2013). A lot of research has been carried out on the effects of neonicotinoids on honey bee populations in agricultural landscapes, but little research has been done to find the effects of neonicotinoids on honey bee populations in urban areas. Neonicotinoids are marketed to residential gardeners for both flowers and vegetables, therefore urban honey bees may also be at risk of exposure (Goulson, 2013).

3.8 Honey Bee Habitat Needs

For honey bees to thrive in an urban environment many habitat needs are required; they need access to good foraging habitat, nesting sites, supportive microclimates, water and a safe, pesticide free environment .

3.8.1 Good Foraging Habitat

Honey bees need good foraging habitat. Providing a high quality food source for honey bees reduces nutritional stress and increases resilience to pests, diseases and pesticide exposure (Newstrom-Lloyd, 2013). Honey bees are herbivorous. Colonies rely on pollen and nectar collected from flowers by worker bees to provide protein, energy and micronutrients needed to survive. Honey bees are also floral generalists, meaning they feed on a wide variety of flower species compared with floral specialists who rely on specific plant species (Proctor, Yeo, & Lack, 1996). Not all plants are created equal (Alaux et al., 2010). The effectiveness of a plants supplying food for honey bees can be determined by factors including shape (Garbuzov, Samuelson, & Ratnieks, 2015) and quality of nectar (Vaudo et al., 2015).

Research suggests floral reward, which is the reward a flower gives to a honey bee in exchange for pollination services often in the form of nectar, influences honey bee foraging choice (Vaudo et al., 2015). Characteristics including sugar composition, nectar volume and nectar concentration all affect how good the floral reward is (Vaudo et al., 2015). Plants with a higher value floral reward which gives the worker bee more energy are the best choice (Vaudo et al., 2015). Nectar composition affects floral reward because nectar it is made up of three different sugars; glucose, fructose and sucrose. Different plant species produce nectar with different sugar compositions (Vaudo et al., 2015) and honey bees prefer plants producing nectar with a high sucrose level (Baker & Baker, 1983). A correlation has been found between host-plant visitation and nectar concentrations (Nicolson, Nepi, & Pacini, 2007). Honey bees prefer flowers with a nectar concentration of 30-50% (Roubik &

Buchmann, 1984) because honey bees are a long tongued species and diluted nectar is easier for them to gather (Vaudo et al., 2015). There is a debate in the literature about honey bees ability to assess the nutritional value of pollen. Roulston and Cane (2000) suggest there is little evidence that honey bees are able to distinguish between pollens with high nutritional value and those with low nutritional value. In contrast Hendriksma and Shafir (2016) found that honey bees are able to actively seek macronutrients that the hive may be lacking. More research is required into the nutritional value of pollen and nectar in flowers, providing decision makers with information regarding plant species with high quality nectar and pollen to support both worker bees and colonies.

To increase efficiency of food collection, honey bees need to use as little energy as possible extracting the floral reward. Flowers with accessible nectar and pollen, and clumps of the same variety of flower are preferable (Newstrom-Lloyd, 2013). Physical features including the length of the tube holding the nectar affect how efficiently a honey bee can gather food from the flower. Flowers with shorter tubes are preferable as less energy is required to gather food (Binkenstein, Stang, Renoult, & Schaefer, 2016). Honey bees prefer flowers to be planted in groups of the same species because they prefer to feed off the same type of flower, allowing them to preserve the energy needed to learn a new flower structure (Alaux et al., 2010; Vaudo et al., 2015). Therefore planting flowers in clusters of the same species could be an effective way of supporting honey bees. In New Zealand, the majority of native plants have evolved to have small, simple and plain coloured flowers. Honey bees are able to easily utilise these flowers as a food source and facilitate pollination (Butz Huryn, 1995).

Honey bees require a stable food supply throughout the entire foraging season, however their nutritional needs change throughout this time. In New Zealand the beekeeping season is divided into four distinct stages. The first season is from the beginning of winter until early spring (June – September). During this time the number of honey bees in the hive drops to under 10,000 to survive the colder winter months (Matheson & Reid, 2018). Little foraging is required to sustain the hive and only a small number of flowers are required to keep the hive alive. The second season is from the beginning of spring until early summer (October – November). During this time the number of bees in each hive is rapidly increasing to reach a peak population of up to 80,000 honey bees (Matheson & Reid, 2018). Good habitat is critical to ensure worker bees are able to collect enough pollen and nectar to feed the growing hive. The third season is summer (December – March) when hives have reached their peak populations (Matheson & Reid, 2018). Ecosystem services in the form of pollination and honey production increase during this time. Honey bees need a stable energy source from flowers within a foraging range. The last season is from autumn until early winter (March – June). During this time the hive starts to slow down and less food for the young brood is needed as brood size begins to drop. However, individual bees require a stable food source as they fatten up to survive the winter (Matheson & Reid, 2018).

Honey bees need connected habitats to survive. Habitat fragmentation occurs when land use changes cause serious habitat degradation. This often results in small isolated patches of appropriate habitat scattered within a matrix of unsuitable habitat (Dauber et al., 2010). In urban areas, honey bees foraging distances range between 461 meters and 1229 meters, fluctuating depending on the seasons and food availability (Garbuzov, Schürch, & Ratnieks, 2015). For honey bees to have sufficient connectivity, a number of habitat patches should be available within 1229 meters of the hive, and ideally located within a 461 meters radius. Honey bee foraging happens at a landscape scale. Therefore, landscape composition has a significant effect on honey bees ability to collect food (Sponsler & Johnson, 2015). Increasing built up urban areas creates a more fragmented landscape and negatively effects honey bees (Plascencia & Philpott, 2017). In urban residential areas there is no possibility of continuous habitat. However, because honey bees are able to travel to collect food, a network of smaller habitat patches located within the foraging range can support honey bee populations.

3.8.2 Nesting sites

Honey bees are cavity nesting bees and need hives to live in (Seeley, 2014). The rise in parasites and diseases such as varroa destructor has been detrimental to wild honey bee populations and for honey bees to survive in New Zealand they need to be in a managed hive which is treated for the mite (Newstrom-Lloyd, 2013; Potts et al., 2010). The Langstrom hive is commonly used to house honey bees because the design fulfills all the nesting needs of the honey bee and allows beekeepers to easily access the bees and honey, and easily relocate the hive (Seeley, 2014).

3.8.3 Microclimate

Honey bees prefer nesting in sites which are sheltered from strong wind, sunny, have good air circulation and are not frosty (Garbuzov & Ratnieks, 2014). Honey bees are able to forage more efficiently in warm, sunny and sheltered areas rather than cool and shaded areas because energy costs are significantly reduced (Stabentheiner & Kovac, 2014).

3.8.4 Water

Honey bees need water both for hydration and for temperature control in the hive (Seeley, 2014). The water needs to be fresh and free of pesticides to avoid contamination. However, it is possible that honey bees gather important micronutrients from muddied water, therefore providing a source of muddied water may increase honey bee health (Abou-Shaara, 2014).

3.8.5 Disturbances

Neonicotinoids negatively affect honey bee health (Gill et al., 2012; Tsvetkov et al., 2017). Ideally for honey bees to thrive neonicotinoids would not be used in a residential garden, if neonicotinoids are used hives should be located outside the foraging range of treated plants.

Chapter 4

Best Practice Criteria for Guidelines

This chapter looks at the definition of a guideline and explores what scholars of guidelines identify as desirable attributes. These attributes will then be used, in part, to evaluate the guidelines for honey bee conservation identified in the systematic literature review. To define guidelines and identify attributes, a narrative review was carried out to find scholarly literature. This was done using a 2-stage search strategy. The first stage was identifying core articles about guideline attributes and success. To do this, Boolean key word searches were carried out using words related to guideline attributes on Google Scholar, Scopus, Web of Science and Taylor and Francis. The second stage was finding additional scholarly literature through references and related article links on databases. The second stage was carried out because the initial search resulted in very few relevant results. Literature from landscape architecture and urban design journals was reviewed. Literature from medical journals was also evaluated because extensive research has been carried out to identify attributes of clinical guidelines which contribute to increased uptake and engagement from practitioners.

4.1 Guideline definition

Guidelines are used in many professions to translate scientific knowledge and experience into principles that can be applied in practice (Klemm, Lenzholzer, & Van Den Brink, 2017; Prominski, 2016). In landscape architecture, guidelines are a key part of evidence based design because they create a strong link between scholarly literature and design implementation (Prominski, 2016). They are a tool which consolidates knowledge on a particular topic, to guide the users through the decision making process, by including recommendations of appropriate actions and excluding recommendations for unsuitable actions (Klemm et al., 2017; Prominski, 2016). Guidelines are presented as a broad set of possible actions that assist practitioners when making design decisions (Klemm et al., 2017; Prominski, 2016). Useful guidelines apply to a range of people or groups (Hooke & Sandercock, 2012) and offer appropriate direction for a generalised set of situations rather than a specific case (Prominski, 2016). Klemm et al. (2017) define guidelines as "*A body of evidence based, universally applicable knowledge that guides urban designer actions in a variety of site specific and functional circumstance that are considered useful by design practitioners".* For this paper a guideline shall be defined as a tool which helps users make decisions (Klemm et al., 2017; Prominski, 2016), that is created using scholarly knowledge and experience as a basis (Gagliardi, Brouwers, Palda, Lemieux-Charles, & Grimshaw, 2009; Klemm et al., 2017) for actionable recommendations which can be used in practice (Klemm et al., 2017; Prominski, 2016).

4.2 Attributes

A review of landscape architecture, urban planning and medical literature identified eight key attributes, described in Table 5.1, which lead to successful guidelines; validity, understandability, implementability, applicability, feasibility, participation, measurability and comprehensiveness.

4.2.1 Validity

Validity was identified as a key guideline attribute in multiple studies from landscape architecture, urban planning and medical literature. Guidelines are a tool to bridge the gap between academia and practice (Gagliardi et al., 2009; Gagliardi, Brouwers, Palda, Lemieux-Charles, & Grimshaw, 2011; Kastner et al., 2015; Klemm et al., 2017). Guideline developers must use research that is current, reliable and transparent to create evidence based guidelines (Kastner et al., 2015).

4.2.2 Understandability

Understandability affects the ease and frequency of guideline use (Azerrad & Nilon, 2006; Gagliardi et al., 2011). The literature review identified three key guideline features affecting understandability: format (Foy et al., 2002; Gagliardi et al., 2011; Grilli & Lomas, 1994; Klemm et al., 2017), language (Azerrad & Nilon, 2006; Gagliardi et al., 2011; Kastner et al., 2015) and graphics (Gagliardi et al., 2011; Klemm et al., 2017). There is agreement among disciplines that to improve understandability, guidelines must be formatted in a way which promotes user comprehension (Gagliardi et al., 2011; Klemm et al., 2017). A review by Gagliardi et al. (2011) stressed the importance of navigational tools such as a table of contents to help the user navigate guidelines and promote ease of use. They also note that supporting evidence should be presented in a way that can be easily interpreted, for example in a narrative or tabulated format. Multiple researchers noted that complexity inhibits use, therefore clear and simple formatting is essential for usability (Gagliardi et al., 2011; Kastner et al., 2015; Klemm et al., 2017). A guideline developer may achieve this through limiting the number of recommendations, limiting the number of steps within each recommendation (Kastner et al., 2015) and using bullet points and lists to structure guideline recommendations (Kastner et al., 2015). Language and writing style also affects clarity of recommendations. Clarity can be improved by using unambiguous, clear and persuasive language, combined with appropriate punctuation and sentence structure (Kastner et al., 2015). Use of images and diagrams to illustrate practical application of recommendations has been found to increase usability and therefore promote guideline implementation (Gagliardi et al., 2011).

4.2.3 Implementability

Implementability is a key focus of guidelines in the medical field (Gagliardi et al., 2011). For guidelines to be implementable, guideline developers must identify possible barriers and develop strategies to overcome them (Gagliardi et al., 2011). Possible barriers to consider may be cost, complexity or user confidence (Gagliardi et al., 2011).

4.2.4 Applicability

Guidelines need to be applicable and easy to use (Gagliardi et al., 2011; Klemm et al., 2017) through the entire design process, from design and planning to implementation (Klemm et al., 2017). Applicable guidelines should provide advice on specific actions required to achieve the guideline's goal (Gagliardi et al., 2009; Woodruff & BenDor, 2016) and have flexibility in their recommendations so they may apply to a variety of site specific situations (Klemm et al., 2017).

4.2.5 Feasibility

Feasibility relates to the ability of the guidelines to be implemented in practice, constraints such as space availability, cost and site situation need to be assessed to establish if the guideline's recommendations can be achieved (Klemm et al., 2017).

4.2.6 Participation

In the landscape architecture and urban planning literature, participation is highlighted as a key attribute for successful guideline development (Klemm et al., 2017; Nassauer & Opdam, 2008; Woodruff & BenDor, 2016). Woodruff and BenDor (2016) believe that via consultation, community members and organizations should have input throughout the entire guideline development process, from identifying issues and creating goals and objectives, to measuring the outcomes. Nassauer and Opdam (2008) stress the importance of different disciplines, from science and practice, working together to create a holistic set of guidelines. A consultation process of some kind should be undertaken during guideline development to ensure relevance to the public and validity of research and experience supporting the recommendations.

4.2.7 Measurability

Measurability is identified as a key attribute for guidelines success. For guidelines to be measurable, clear and understandable goals and objectives need to be identified (Gagliardi et al., 2011). Both goals and objectives are required as they serve different purposes. A goal is a long-term direction which is difficult to measure. The goal needs to be supported by objectives which are a set of quantifiable targets which collectively establish that the goal has been achieved (Hodge, 1986).

4.2.8 Comprehensiveness

While there is no mention in the literature, it is likely that guidelines need to be comprehensive to be successful. Comprehensiveness is defined as incorporating integrated considerations of multiple factors which influence guidelines success rather than an isolated approach (Handelsman et al., 2011).

Table 4.1 Evaluation of guidelines

Attribute	Definition	No. of references	Disciplines	References
Validity	Research and experiences used to create the guidelines must be evidence-based, reliable, current and transparent .	8	Landscape Architecture Urban Planning Medicine	(Kastner et al. 2015; Woodruff & BenDor, 2016; Gagliardi et al., 2011; Gagliardi et al., 2009; Straus and Haynes, 2009; Klemm, Lenzolzer & van den Brink, 2015; Brown & Corry, 2011; Prominski, 2016)
Understandability	How easily can the guidelines be comprehended? Simple, clear, concise and organised language and formatting leads to greater understandability.	7	Landscape Architecture Urban Planning Medicine	(Gagliardi et al., 2011; Klemm, Lenzolzer & van den Brink, 2017; Klemm, Lenzolzer & van den Brink, 2017; Azerrad & Nilson 2006; Kastner et al. 2015; Grilli & Lomas, 1994; Foy et al., 2012)
Applicability	Provision of clear and specific actions in a specific context.	5	Landscape Architecture Urban Planning Medicine	(Klemm, Lenzolzer & van den Brink, 2015; Klemm, Lenzolzer & van den Brink, 2017; Woodruff & BenDor, 2016; Gagliardi et al., 2011; Gagliardi et al., 2009)
Implementability	Identifying and overcoming barriers of use eg. Cost, complexity and user values.	5	Medicine	(Gagliardi et al., 2011; Shiffman et al., 2011; Burgers et al., 2003; Cochrane et al., 2007
Feasibility	Ability for actions to be carried out in practice.	4	Landscape Architecture Urban Planning Medicine	(Klemm, Lenzolzer & van den Brink, 2017; Gagliardi et al., 2011; Azerrad & Nilson 2006; Kastner et al. 2015)
Participation	Involvement from various individuals and groups in the guideline development process.	3	Landscape Architecture Urban Planning	(Klemm, Lenzolzer & van den Brink, 2015; Woodruff & BenDor, 2016; Naussauser & Opdam, 2008)
Measurability	Identification of goals and objectives so guideline success is quantifiable.	2	Landscape Architecture Urban Planning Medicine	(Woodruff & BenDor, 2016; Gagliardi et al., 2011)
Comprehensiveness	Incorporating integrated considerations of multiple factors which influence guideline success rather than an isolated approach.	0		

4.3 Landscape Architecture Guidelines

A search of the Landscape and Planning journal, the Urban Forestry and Urban Greening journal, and the Journal of Landscape Architecture was carried out to find examples of academic guidelines from the landscape architecture field published in the last 15 years. Six guidelines were found (Azerrad & Nilon, 2006; Cariñanos & Casares-Porcel, 2011; Hooke & Sandercock, 2012; Klemm, Lenzholzer, & van den Brink, 2015; Klemm et al., 2017; Woodruff & BenDor, 2016) and assessed to establish a more specific set of attributes associated with communicating guideline recommendations to the user in landscape architecture and urban design (Table 4.2).

The most common communication tool used in academic landscape architecture and urban design guidelines is a table which was used in all six guidelines (Azerrad & Nilon, 2006; Cariñanos & Casares-Porcel, 2011; Hooke & Sandercock, 2012; Klemm, Lenzholzer, & van den Brink, 2015, 2017; Woodruff & BenDor, 2016), compared with bullet points which was only used in one guideline (Klemm et al., 2017). This finding suggests that the disciplines see tables as the most effective way to communicate recommendations to the guideline users. Flow charts were also used on more than one occasion to show both how guidelines were developed and to be used. Flow charts are often used to show a progression over time. There was little consistency in the visual supplements used within the guidelines. Some used photographs (Hooke & Sandercock, 2012; Klemm et al., 2015, 2017) and diagrams (Hooke & Sandercock, 2012; Klemm et al., 2017) to help illustrate a recommendation, where others used maps and plans (Hooke & Sandercock, 2012). Further research is required to establish which visual communication tools are most effective for guidelines in landscape architecture .

Table 4.2 Visual communication tools used in Landscape and Urban Design Guidelines

Communication tool	No. of papers	References
Tables	6	(Azerrad & Nilon, 2006; Cariñanos & Casares-Porcel, 2011; Hooke & Sandercock, 2012; Klemm et al., 2015, 2017; Woodruff & BenDor, 2016)
Flow chart	3	(Hooke & Sandercock, 2012; Klemm et al., 2015, 2017)
Photographs	2	(Hooke & Sandercock, 2012; Klemm et al., 2015, 2017)
Diagrams	2	(Hooke & Sandercock, 2012; Klemm et al., 2017)
Maps	1	(Hooke & Sandercock, 2012)
Plan	1	(Hooke & Sandercock, 2012)
Bullet points	1	(Klemm et al., 2017)

Chapter 5

Systematic Review of Guidelines

5.1 Method

This review was carried out using the search methodology of Gough, Oliver, and Thomas (2017). Searches were conducted of literature found in academic journals published in English and on databases including Scopus, Web of Science, JSTOR, Avery and Taylor and Francis. To ensure research was up to date and relevant the search only covered papers from the last 10 years 2008-2018, and to ensure a high quality of research, only peer reviewed academic literature was considered. Papers chosen looked at guidelines for honey bee conservation.

The searches were carried out using Boolean functions to combine keywords (Appendix A). Key words described the species focus, for example, honey bee or synonyms (eg. *Apis mellifera*), guidelines or synonyms (eg. recommendations) and the setting, for example, yard or synonyms (eg. garden). The search for yards and gardens resulted in few papers so the search parameters were extended to include urban, habitat and synonyms. Similarly, the search for honey bees resulted in few papers so the search parameters were extended to include pollinators. The search was concluded when the results were largely duplicates of literature found in a previous search. The titles and abstracts of the ninety seven results were then screened further using the PRISMA technique, described by Higgins and Green (2011), to ensure the focus species was either honey bees or pollinators and results were guidelines. The full text of the remaining literature was screened using the same process. The criteria for a piece of academic literature to be defined as a guideline are; it must be a tool helping users make decisions (Klemm et al., 2017; Prominski, 2016), it must be derived from a consolidation of scholarly knowledge and experience (Gagliardi et al., 2009; Klemm et al., 2017) and it must provide actionable recommendations for use in practice (Klemm et al., 2017; Prominski, 2016).

An analysis of the final selection was carried out to determine common themes identified by Gough et al. (2017) including year of publication, author, academic journal, academic discipline, geographical location, climate zone and topic of study . Additional themes were also identified including; scale, land use focus, target audience, honey bee needs addressed (Table 6.1), human needs addressed (Table 6.2) and guidelines attributes identified (Table 6.3).

5.2 Overall findings

This review resulted in eight academically substantiated guidelines for honey bee conservation. All research came out of countries located in the Northern Hemisphere; three from the United Kingdom, three from the United States, one from Luxemburg and one from Malta. Nearly all research was conducted in a temperate climate similar to that of New Zealand with warm summers and cool winters, with the exception of Malta which has a Mediterranean climate. All guidelines came from countries or regions affected by colony collapse disorder and experiencing significant declines in honey bee populations (Potts et al., 2010). The eight papers were published in six different journals, all from the science field. The two journals with multiple results were the Journal of Apicultural Research and Frontiers in Ecology and the Environment. No papers were found in design, landscape architecture or planning journals. All authors were found in one publication only.

5.2.1 Scale

The review found the guidelines for honey bees focused on different ecological scales. Guidelines were divided into three scales of conservation; microscale, mesoscale and macroscale. Microscale encompasses all guidelines offering local scale recommendations for honey bee conservation (Sodhi, Butler, Laurance, & Gibson, 2011). Microscale guidelines can be broken into smaller scales based on the physical or geological range of the species (Johnson, 1980) for example, home range (Wheatley & Johnson, 2009) or habitat patches (Holland, Bert, & Fahrig, 2004). Only one of the guidelines reviewed goes into detail of patch size or home range (Garbuzov & Ratnieks, 2014). Mesoscale encompasses guidelines offering recommendations at a regional scale often through policy. Macroscale conservation is conducted on a global scale often through international legislation, for example, limiting unsustainable business practices or through global campaigns inciting public pressure (Sodhi et al., 2011). The literature review found three guidelines focused on a microscale (Garbuzov & Ratnieks, 2014; Mueller & Pickering, 2010; Silva & Minor, 2017), three guidelines focused on both the mesoscale and the microscale (Isaacs, Tuell, Fiedler, Gardiner, & Landis, 2009; Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013) and two guidelines focused solely on a mesoscale (Clermont, Eickermann, Kraus, Hoffmann, & Beyer, 2015; Zammit-Mangion, Meixner, Mifsud, Sammut, & Camilleri, 2017). No guideline focused on macroscale.

Scale is an important factor when recommending changes to a species habitat (Holland et al., 2004). Honey bee conservation needs to be considered at multiple scales to be successful (Sodhi et al., 2011) because honey bees have a large foraging range (Garbuzov, Schürch, et al., 2015). This means honey bees are affected by the habitat characteristics of an individual patch, as well as the characteristics of the surrounding landscape (Holland et al., 2004). The mesoscale was the most common focus of guidelines, closely followed by microscale. However only one guideline zoomed into an individual patch (Garbuzov & Ratnieks, 2014) and the primary focus of this guideline was improving human safety, rather than improving honey bee habitat. This shows a gap in guidelines focusing on interventions for individual habitat patches, which are essential if honey bee conservation is to succeed.

None of the guidelines reviewed looked at honey bee conservation at a macroscale. This may be because implantation of guidelines at this scale requires substantial funding and political and public support to succeed (Sodhi et al., 2011). Isaacs et al. (2009) note honey bee conservation is happening at a macroscale, because pollinator protection programs are fuelled by public pressure. However, no recommendations are offered in the guidelines reviewed to encourage future macroscale change.

5.2.2 Land Use Focus

Land use activities have transformed much of the earth's terrestrial surface. This affects the balance between providing for humans and protecting natural ecosystems which support humans by providing a stable food supply, freshwater, good air quality and climate regulation services (Foley et al., 2005). The guidelines reviewed considered four land uses; agricultural, urban, forestry and industrial. Five guidelines focused, at least partially, on agricultural landscapes (Isaacs et al., 2009; Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017). Agricultural landscapes are landscapes developed for food production, either through croplands or through pasture for animals. Intensive agriculture is the most dominant land use in the world occupying 38% of the land globally (Foley et al., 2011). Only one set of guidelines looked solely at agricultural landscapes (Isaacs et al., 2009), the other four covered agricultural landscapes but also considered other land uses. Sutherland et al. (2014) covered the most extensive range with urban, agricultural and forestry. Urban and agricultural landscapes were both covered by two guidelines (Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017). Three guidelines focused solely on urban landscapes (Garbuzov & Ratnieks, 2014; Mueller & Pickering, 2010; Silva & Minor, 2017). Clermont et al. (2015) looked at urban and industrial.

Different land use types offer different challenges and opportunities for enhancing quality and quantity of foraging habitat, managing pests and diseases, and limiting exposure to pesticides (Clermont et al., 2015). The most common land use focus in the literature review was agricultural landscapes. Factors contributing to this finding may include the dominance of agricultural landscapes worldwide, and the severe degradation of natural honey bee habitat following modern agricultural intensification (Foley et al., 2005). Honey bees contribute greatly to the economic value of rural agricultural landscapes through crop pollination, creating an incentive for further research (Clermont et al., 2015; Issacs et al., 2009).

Urban areas have less of a focus for honey bee conservation efforts. The guidelines focusing on urban landscapes often provided recommendations to protect humans and raise awareness for the importance of pollinators, rather than recommendations to enhance honey bee habitat. Recommendations for urban habitat enhancement were only offered in two guidelines (Clermont et al., 2015; Sutherland et al., 2014). Sutherland et al. (2014) offered two recommendations for urban habitat enhancement compared with twenty two recommendations for agricultural areas in the same set of guidelines. This supports the theory that agricultural landscapes have been the primary focus of honey bee conservation efforts in the past. There is a need for more attention to be paid to other land use types to avoid further honey bee populations declining (Clermont et al., 2015), in particular urban areas, which offer numerous opportunities for habitat enhancement within residential yards.

5.2.3 Target audience

Within the final guideline selection six target audiences were identified; policy makers, beekeepers, school students, educators, scientists and entrepreneurs. Policy makers were the largest target audience with three guidelines aimed at them (Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017). Beekeepers were the target audience of two guidelines (Clermont et al., 2015; Garbuzov & Ratnieks, 2014), as were school students and educators (Mueller & Pickering, 2010; Silva & Minor, 2017). Isaacs et al. (2009) had a multidisciplinary focus hoping to influence scientists, entrepreneurs and educators to effect change. No guidelines looked explicitly at urban residents as a target audience. Two guidelines did however focus on educators and school children (Mueller & Pickering, 2010; Silva & Minor, 2017) who may reside in an urban area. There is also a notable absence of guidelines targeting landscape architects and urban designers.

5.2.4 Honey Bee Needs and Recommendations

The needs of honey bees identified in the narrative literature review include good foraging habitat, good foraging networks, nesting sites, access to water, a supportive microclimate, protection from pests and diseases, and no exposure to pesticides. This review evaluated whether these needs were addressed in the guidelines and looked at what recommendations offered (Table 5.1).

Six authors offered recommendations for creating good foraging habitat, making it the most commonly addressed need. Recommendations included habitat creation (Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013), enhancement of existing habitats (Isaacs et al., 2009; Sutherland et al., 2014) and increasing public engagement in habitat conservation through education (Mueller & Pickering, 2010; Silva & Minor, 2017). Two guidelines suggested introduction of policies to help improve honey bee habitat (Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013). Policy recommendations included strategic planning, introduction of appropriate incentives (Vanbergen & Insect Pollinators, 2013) and encouraging appropriate planting in municipal areas (Sutherland et al., 2014).

Recommendations which limit exposure to pesticides are made in three guidelines (Isaacs et al., 2009; Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013). Recommended actions include; avoiding use of pesticides during flowering and times when honey bees are active (Sutherland et al., 2014), and increasing honey bee nutrition to create resilience to pesticide exposure (Vanbergen & Insect Pollinators, 2013). All three guidelines suggested introduction of policies to reduce exposure to pesticides. Policy recommendations include appropriate restrictions, risk assessment protocols and conservation programs to control pesticide use at a government level (Isaacs et al., 2009; Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013).

Increasing connectivity between foraging habitats is recommended in only two guidelines (Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013), recommendations for appropriate nesting sites are offered in two guidelines (Clermont et al., 2015; Garbuzov & Ratnieks, 2014) and recommendations for access to a safe water supply are also offered in two guidelines (Clermont et al., 2015; Sutherland et al., 2014). Recommendations for protection from pests (Zammit-Mangion et al., 2017) and recommendations for protection against diseases (Vanbergen & Insect Pollinators, 2013) are only offered in one guideline. No guidelines offer recommendations for a supportive microclimate for honey bees.

Table 5.1 Honey Bee Needs Addressed

Honey Bee Need	No. guidelines addressing needs	Guidelines addressing need	Recommendations
Good Foraging Habitat	6	(Clermont et al., 2015) (Isaacs et al., 2009) (Mueller & Pickering, 2010) (Sutherland et al., 2014) (Silva & Minor, 2017) (Vanbergen & Insect Pollinators, 2013)	HABITAT ENHANCEMENT Protect, restore and enhance habitat (Isaacs et al., 2009; Sutherland et al., 2014) Habitat creation, restoration and rewilding (Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013) Planting a diverse range of nectar and pollen providing plants (Sutherland et al., 2014) Increasing conservation awareness and civic duty through education (Mueller & Pickering, 2010; Silva & Minor, 2017) Introducing pollinator habitat into schools to promote honey bee conservation through education (Mueller & Pickering, 2010; Silva & Minor, 2017) Getting school students gardening and observing bees (Mueller & Pickering, 2010; Silva & Minor, 2017) POLICY Strategic planning and devising appropriate initiatives (Vanbergen & Insect Pollinators, 2013) To encourage planting of appropriate resource plants in gardens and municipal areas (Sutherland et al., 2014)
Disturbances	3	(Isaacs et al., 2009) (Sutherland et al., 2014) (Vanbergen & Insect Pollinators, 2013)	Enhancing nutrition to increase honey bees reliance to exposure to pesticides (Vanbergen & Insect Pollinators, 2013) Apply pesticides at night (Sutherland et al., 2014) Avoid using pesticides during flowering (Sutherland et al., 2014) Apply pesticides at ground level (Sutherland et al., 2014) POLICY Create Risk Assessment Protocols (Vanbergen & Insect Pollinators, 2013) Restrict pesticides such as neonicotinoids (Sutherland et al., 2014) Increased biological pest control through conservation programs (Isaacs et al., 2009)
Connectivity between Foraging Habitats	2	(Sutherland et al., 2014) (Vanbergen & Insect Pollinators, 2013)	Sowing flowers and plants to minimise spatial gaps (Vanbergen & Insect Pollinators, 2013) Improve landscape-scale connectivity (Sutherland et al., 2014)
Appropriate Nesting Sites	2	(Clermont et al., 2015) (Garbuzov & Ratnieks, 2014)	Apiaries sites should be primarily in agricultural landscapes (Clermont et al., 2015) Forest managers should provide management plans to beekeepers so hives can be moved from forests before forest clear-cuts (Clermont et al., 2015) Barriers should be placed around hives (Garbuzov & Ratnieks, 2014)
Access to Safe Water	2	(Clermont et al., 2015) (Sutherland et al., 2014)	Keep bodies of water pesticide free (Sutherland et al., 2014) Place hives away from artificial water (Clermont et al., 2015)
Protection from Pests and diseases	2	(Vanbergen & Insect Pollinators, 2013) (Zammit-Mangion et al., 2017)	Restrict importation of foreign honey bees (Zammit-Mangion et al., 2017) Enhancing nutrition to increase honey bees reliance to pests and diseases (Vanbergen & Insect Pollinators, 2013)
A Supportive Microclimate	0		

5.2.5 Human Needs and Recommendations

This review evaluated whether the needs of humans were addressed in the guidelines and looked at what recommendations were offered (Table 5.2).

The needs of humans in relation to honey bees include safety and continued ecosystem services. Recommendations to improve human safety around honey bees are offered in three guidelines (Garbuzov & Ratnieks, 2014; Mueller & Pickering, 2010; Silva & Minor, 2017). Recommendations include fencing around apiaries to reduce stings (Garbuzov & Ratnieks, 2014) and educating school students to increase awareness (Mueller & Pickering, 2010; Silva & Minor, 2017).

Ecosystem services refer to ecological conditions, processes and life supporting functions which support human wellbeing (Millennium Ecosystem Assessment, 2005). Declines in ecosystem services have the potential for a serious negative impact on the quality of human life (Fisher, Turner, & Morling, 2009). Research has found a correlation between healthy ecosystems and human wellbeing (Millennium Ecosystem Assessment, 2005). Therefore there is a need to maintain, enhance and restore ecosystem services. Six of the guidelines discuss the benefits of pollination ecosystem services honey bees provide (Clermont et al., 2015; Isaacs et al., 2009; Silva & Minor, 2017; Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013). However, there is little in the recommendations focusing explicitly on conserving these services in practice (Sutherland et al., 2014). Only one guideline makes a recommendation purely addressing ecosystems services (Vanbergen & Insect Pollinators, 2013). Clermont et al. (2015) and Silva and Minor (2017) also acknowledges the ecosystem services honey bees provide, through production of honey, however no recommendations directly relating to provisioning ecosystem services are offered.

Table 5.2 Human Needs Addressed

Human Need	No. guidelines addressing needs	Guidelines addressing need	Recommendations
Safety	3	(Garbuzov & Ratnieks, 2014) (Mueller & Pickering, 2010) (Silva & Minor, 2017)	Recommend using barriers around hives (Garbuzov & Ratnieks, 2014) Educate adolescents to improve knowledge and understanding to make them less afraid of bees (Silva & Minor, 2017) Educate children and parents about anaphylaxis (Mueller & Pickering, 2010)
Ecosystem Services	1	(Vanbergen & Insect Pollinators, 2013)	Use other bee species in crop pollination to minimise risk of outbreaks of disease which may compromise the ecosystem services honey bees provide (Vanbergen & Insect Pollinators, 2013)

5.2.6 Guideline Attributes

This review evaluated whether guidelines contained key attributes including validity, understandability, applicability, implementability, feasibility, participation, measurability and comprehensiveness (Table 5.3).

Validity

Validity was the only attribute which was found in all 8 guidelines (Clermont et al., 2015; Garbuzov & Ratnieks, 2014; Isaacs et al., 2009; Mueller & Pickering, 2010; Silva & Minor, 2017; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017). This suggests that guideline creators believe that for guidelines to be successful they must be based on research and evidence.

Understandability

Six of the guidelines used clear understandable language (Garbuzov & Ratnieks, 2014; Mueller & Pickering, 2010; Silva & Minor, 2017; Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017). However, the recommendations were often hidden within the body of text and considerable effort was required by the reader to find them. Only two guidelines were formatted in a simple and clear manner, both used clear headings and bullet points, allowing the user to quickly pick up key recommendations (Mueller & Pickering, 2010; Sutherland et al., 2014).

Applicability

Half of the guidelines found in the review offered recommendations which were easily applicable and could be applied in a range of contexts (Garbuzov & Ratnieks, 2014; Mueller & Pickering, 2010; Silva & Minor, 2017; Sutherland et al., 2014). Sutherland et al. (2014) separated recommendations into the different ecosystem services they helped support including air quality, climate regulation, water flow regulation and pollination and provided a list of interventions for each. Interventions were then categorized by land use, for example forests, agricultural and urban. This approach allows the user to tailor the guidelines to their needs and geographical location. Silva and Minor (2017) and Mueller and Pickering (2010) gave recommendations which could be used in many different school environments, including encouragement of garden activities to promote pollinator awareness. Garbuzov and Ratnieks (2014) recommended fencing around apiaries to increase the safety of humans and this recommendation can also be implemented in many different situations. Half of the guidelines offered recommendations which were only applicable in specific situations, limiting opportunities for execution.

Implementabilty

Three sets of guidelines address implementability by identifying any barriers to guideline success and suggesting strategies to overcome said barriers (Garbuzov & Ratnieks, 2014; Mueller & Pickering, 2010; Sutherland et al., 2014). Barriers to guideline success identified include cost (Garbuzov & Ratnieks, 2014; Sutherland et al., 2014), human safety (Garbuzov & Ratnieks, 2014; Mueller & Pickering, 2010), the potential for undesirable outcomes (Sutherland et al., 2014) and human perception (Garbuzov & Ratnieks, 2014). Strategies were then developed to overcome these barriers making the guidelines implementable. Key strategies included cash incentives or tax disincentives (Sutherland et al., 2014), education (Mueller & Pickering, 2010) and promotion of positive outcomes (Garbuzov & Ratnieks, 2014).

Feasibility

Feasibility relates to recommendations being able to be carried out in practice (Klemm et al., 2017). It is possible that all guideline recommendations are feasible, however context is required to determine feasibility. Characteristics including space availability, cost and site situation need to be assessed to establish if the guideline recommendations can be achieved (Klemm et al., 2017).

Participation

Evidence of input from a wide range of experts was found in only one set of guidelines (Sutherland et al., 2014). Sutherland et al. (2014) worked with a group of experts to develop their guidelines. Firstly small groups of experts in a specific field collaborated to create initial recommendations which were then circulated to a wider circle of experts and organizations for further input. This approach helps to create a more holistic set of recommendations (Nassauer & Opdam, 2008). No other guideline developers consulted professionals or the public during the development process. Consequently, the issues, goals and recommendations identified may not align with the views within the field or the wider public.

Measureability

Goals and objectives are required for guidelines to be measurable. Only one set of guidelines identified a goal, Mueller and Pickering (2010) clearly stated their goal was to *'help students educate others to revitalise pollinator populations and take other actions'.* However there is a lack of clear objectives and without quantifiable objectives it is difficult for success to be measured. Sutherland et al. (2014) acknowledge the need for measurability in guidelines, suggesting developing tools to measure changes in ecosystem health resulting from implementation of recommendations. The data collected would then be used to monitor and improve management strategies (Sutherland et al., 2014). However, there is a lack of clear goals and objectives and these would be required to make appropriate choices regarding improving management strategies.

Comprehensiveness

None of the guidelines found in the review are comprehensive. Sutherland et al. (2014) recognizes their list of recommendations will never be fully comprehensive because of the complex nature of the guidelines. Uncomprehensive guidelines could lack key recommendations which may be crucial for success.

Table 5.3 Guideline Attributes Identified

Validity	Yes	References	No	References
Are the guidelines evidence-based? Is the evidence reliable, current and transparent, are references provided?	8	(Clermont et al., 2015; Garbuzov & Ratnieks, 2014; Isaacs et al., 2009; Mueller & Pickering, 2010; Silva & Minor, 2017; Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017)	0	
Understandability				
Is the language used in the guidelines simple, clear and concise?	6	(Garbuzov & Ratnieks, 2014; Mueller & Pickering, 2010; Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017)	2	(Clermont et al., 2015; Isaacs et al., 2009)
Is the format clear, simple and organised?	2	(Mueller & Pickering, 2010; Sutherland et al., 2014)	6	(Clermont et al., 2015; Garbuzov & Ratnieks, 2014; Isaacs et al., 2009; Silva & Minor, 2017; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017)
Applicability				
Are clear actions provided for a range of contexts?	4	(Garbuzov & Ratnieks, 2014; Mueller & Pickering, 2010; Silva & Minor, 2017; Sutherland et al., 2014)	4	(Clermont et al., 2015; Isaacs et al., 2009; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017)
Implementability				
Are barriers identified?	3	(Garbuzov & Ratnieks, 2014; Mueller & Pickering, 2010; Sutherland et al., 2014)	5	(Clermont et al., 2015; Isaacs et al., 2009; Silva & Minor, 2017; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017)
Are strategies to overcome barriers identified?	3	(Garbuzov & Ratnieks, 2014; Mueller & Pickering, 2010; Sutherland et al., 2014)	5	(Clermont et al., 2015; Isaacs et al., 2009; Silva & Minor, 2017; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017)
Feasibility				
Are the actions and recommendations able to be carried out in practice?	NA	(Clermont et al., 2015; Isaacs et al., 2009; Mueller & Pickering, 2010; Silva & Minor, 2017; Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017)		
Participation				
Are a range of individuals and organizations involved in the guideline development process?	1	(Sutherland et al., 2014)	7	(Clermont et al., 2015; Garbuzov & Ratnieks, 2014; Isaacs et al., 2009; Mueller & Pickering, 2010; Silva & Minor, 2017; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017)
Measurability				
Are clear goals identified?	1	(Mueller & Pickering, 2010)	7	(Clermont et al., 2015; Garbuzov & Ratnieks, 2014; Isaacs et al., 2009; Silva & Minor, 2017; Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017)
Are measurable objectives identified to support goals?	1	(Sutherland et al., 2014)	7	(Clermont et al., 2015; Garbuzov & Ratnieks, 2014; Isaacs et al., 2009; Mueller & Pickering, 2010; Silva & Minor, 2017; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017)
Comprehensive				
Are integrated considerations of multiple factors considered in guidelines?	0		8	(Clermont et al., 2015; Isaacs et al., 2009; Mueller & Pickering, 2010; Silva & Minor, 2017; Sutherland et al., 2014; Vanbergen & Insect Pollinators, 2013; Zammit-Mangion et al., 2017)

Landscape Architecture Guideline Attributes

Finally, guidelines were assessed to establish if they used any of the visual communication tools found in the earlier review of landscape architecture or urban design guidelines. No guidelines came from these fields, however some of the communication tools were still used. Five guidelines used tables as a communication tool (Clermont et al., 2015; Isaacs et al., 2009; Mueller & Pickering, 2010; Silva & Minor, 2017; Sutherland et al., 2014), three guidelines used photographs (Garbuzov & Ratnieks, 2014; Isaacs et al., 2009; Mueller & Pickering, 2010), two used bullet points (Mueller & Pickering, 2010; Sutherland et al., 2014) and two used maps (Clermont et al., 2015; Zammit-Mangion et al., 2017). Plans were only used in one guideline (Garbuzov & Ratnieks, 2014) as were diagrams (Vanbergen & Insect Pollinators, 2013). Flow charts were not found in any of the guidelines. The use of similar techniques suggests there may be opportunities for cross over between guidelines from different academic fields and professions.

5.3 Limitations in Research Methods

The review was restricted to academic peer reviewed literature to ensure guidelines were evidence based and of a high quality. It is likely a number of guidelines for supporting honey bees in an urban environment which are not academically substantiated exist. However, these guidelines may offer recommendations which without supporting research, may be unreliable and outcomes may vary.

Chapter 6

Discussion

6.1 Gaps in knowledge

There are no academically substantiated guidelines available which provide a comprehensive list of recommendations, for urban residents and landscape architects, to enhance honey bee habitat in urban yards. While guidelines for honey bee conservation are available they tend to offer a broad set of conservation recommendations for large scale implementation, rather than actionable recommendations for smaller projects such as residential yards. Honey bees have the ability to move freely within their foraging range, visiting a number of different habitat patches (Garbuzov, Schürch, et al., 2015). It is important that these individual habitat patches are designed to provide sustainable and safe habitat for honey bees. There is a gap in knowledge regarding the habitat needs of honey bees in urban environments. Considerable research has been carried out in agricultural areas, driven by the rise in Colony Collapse Disorder and the potentially detrimental effects of honey bee declines on the agricultural sector (Clermont et al., 2015; Issacs et al., 2009). As a result, guidelines are available for enhancing honey bee habitat in agricultural areas. Some of the agricultural guideline recommendations are transferable, however the urban environment creates a unique set of challenges and opportunities for supporting honey bees. A multidisciplinary approach to further research is required to investigate how the needs of honey bees in an urban environment differ from those in an agricultural environment and how these needs can be met in practice.

Best practice criteria for landscape architecture guidelines are limited. More exhaustive research is required to determine the key attributes leading to successful implementation and achieving desired goals for guidelines in the landscape architecture field. This review provides a platform for the creation of experimental guidelines for designing honey bee habitat in residential yards. Guidelines created could be used in further research into the key attributes required for landscape architecture guidelines.

6.2 Implication for Residents and Landscape Architects

This review demonstrates that there are many possibilities for enhancing honey bee habitat in residential yards. Enhancing habitat would help improve regulating, provisioning and cultural ecosystem services in urban environments. However, there is currently a lack of guidelines bridging the gap between research and practice (Clark & Dickson, 2003). This creates an opportunity for landscape architects to collaborate with experts and urban residents to create guidelines, helping urban residents design and manage their yards in a way which benefits both honey bees and humans.

Urban residents and landscape architects would benefit from the creation of academically substantiated guidelines. Guidelines consolidate research into simple recommendations, helping inform design and management decisions (Klemm et al., 2017; Prominski, 2016), therefore creating a tool which can be used for enhancing honey bee habitat in residential yards. Improved habitat leads to healthier honey bees (Alaux et al., 2010) and consequently a greater honey yield (Mattila & Otis, 2006) and more reliable pollination services. Improving honey bee habitat also generates larger areas of green space within the urban environment, creating more opportunities for urban residents to experience closeness to nature and improve human wellbeing. Raising awareness for the ecosystem services honey bees provide will hopefully lead to an increase in civic ecological practices, a term coined to describe local, hands-on environmental stewardship actions (Krasny & Tidball, 2012). Partnerships formed between professionals and communities to promote stewardship can be an effective response to ecological degradation in urban environments (Krasny & Tidball, 2012) and guidelines are an effective tool to inform actions which can be undertaken to enhance urban ecosystems.

The creation of guidelines would also benefit urban beekeepers. Colony loss has been found to be significantly higher in hives managed by hobbyists and the majority of hobbyist apiaries are located in populated areas (Brown et al., 2018; Lee et al., 2015). Therefore, they rely on urban green spaces such as residential yards to provide foraging habitat for their hives (Brown et al., 2018). Guidelines would give urban residents the information required to design honey bee habitat within their properties and create a more sustainable food source for urban honey bees. Enhancing honey bee nutrition improves their health. This creates more resilient honey bees, able to withstand other disturbances including pesticide exposure, pests and diseases (Vanbergen & Insect Pollinators, 2013), therefore decreasing the risk of colony loss.

Landscape architects were not considered in the creation of any of the guidelines reviewed, despite the increased involvement of landscape architects in similar projects preserving, restoring and enhancing biodiversity, often in conjunction with landscape ecologists and other professionals (Collinge, 1996). An increase in research in the last ten years has created a greater understanding of honey bee habitat needs and the effects human induced stresses are having on honey bee populations. The landscape architecture profession has a unique opportunity to work with researchers and residents to help increase urban sustainability. Guidelines can be used as a tool to help landscape architects by creating a set of recommendations to inform design decisions. The landscape surrounding residential yards also significantly influences honey bees ability to survive in an urban environment. All landscape architects working in urban areas have the opportunity to consider design interventions which benefit honey bees. Unlike most researchers, landscape architects have the ability to integrate the findings from ecological studies into the physical landscape on multiple occasions through different projects. The challenge the landscape architecture discipline faces is balancing integrated evidence based ecological principles, to create more sustainable honey bee habitat, with the economic and social values of humans (Zipperer, Wu, Pouyat, & Pickett, 2000).

Chapter 7

Conclusions

There is clear evidence that honey bees are threatened (Potts et al., 2010). Honey bees provide important ecosystem services to humans, both through provisioning ecosystem services in the form of food and medicinal products (Pasias et al., 2018), regulating service through pollination (Genersch, 2010) and cultural services through connection to nature (Streimikiene, 2015). There is an opportunity in residential yards to enhance habitat quality and connectivity for urban honey bee populations, therefore improving the species resilience to other disturbances including pesticide use, pests and diseases (Vanbergen & Insect Pollinators, 2013). Guidelines act as an appropriate tool to translate research into recommendations which can be easily implemented in practice (Klemm et al., 2017; Prominski, 2016). Despite this there is a dearth in academically substantiated guidelines to help residents enhance habitat in their yards to support honey bees. More exhaustive research is required to identify the needs of honey bees and humans in residential yards and to inform the creation of valid, understandable, applicable, implementable, feasible, participatory and measurable guidelines for urban residents and landscape architects.

Appendix A

Systematic Literature Review

A.1 Boolean Word Search for Systematic Literature Review

(“Honey bee*” or honeybee* or “Apis mellifera” OR Apiculture OR Pollinator*) AND

(Yard OR garden OR residential OR urban OR metropolitan OR metropolis OR town OR suburb* OR habitat OR landscape) AND

(Guidelines OR guide* OR direction* OR recommendation*OR regulation*OR standard* OR protocols OR “Landscape management” OR initiative OR plan OR Framework OR model)

A.2 Papers Identified in Systematic Literature Review

Authors	Year	Journal	Name of paper	Location	Needs addressed	Land use focus	Target group
Garbuzov & Ratnieks	2014	Journal of Apiculture Research	Lattice fence and hedge barriers around an apiary increase honey bee flight height and decrease stings to people nearby	UK	Human	Urban	Beekeepers
Zammit-Mangion et al	2017	Journal of Apiculture Research	Thorough morphological and genetic evidence confirm the existence of the endemic honey bee of the Maltese Islands Apis mellifers ruttneri: recommendations for conservation	Malta	Bee	Multiple	Policy makers
Clermont et al.	2015	Environmental Research and Innovation	Correlations between land covers and honey bee colony loss in a country with industrialized and rural regions	Luxemburg	Bees	Multiple	Beekeepers
Mueller & Pickering	2010	Science Activities	Bee Hunt! Ecojustice in practice for earths buzzing biodiversity	USA	Humans & Bees	Urban	School children
Silva & Minor	2017	Anthrozoos	Adolescents experience and knowledge of attitudes towards, bees: implications and recommendations for conservation	USA	Humans & Bees	Urban	School children
Sutherland et al.	2014	Ecology and Society	Solution scanning as a key policy tool identifying management interventions to help maintain and enhance regulating ecosystem services	UK	Bees	Multiple	Policy makers
Issacs et al.	2009	Frontiers in Ecology and the Environment	Maximising arthropod mediated ecosystem services in agricultural landscapes: the role of native plants	USA	Bees	Agricultural	Scientists, Entrepreneurs and Educators
Vandergen & Insect pollinators initiative	2013	Frontiers in Ecology and the Environment	Threats to an ecosystem service: pressures on pollinators	UK	Bees	Agricultural	Policy makers

Appendix B

B.1 A critical review of the challenges and opportunities for supporting honey bees *Apis Mellifera* in urban residential areas of New Zealand

Honey bees and humans have a mutually beneficial relationship. Honey bees provide us with honey and pollination services and beekeepers provide hives and food for the bees. In New Zealand honey bees were introduced primarily for honey production (Howlett & Donovan, 2010), however honey bees have become important pollinators for a number of edible crops (Potts et al., 2010), without honey bees the global food supply would be in jeopardy.

In the last 12 years there has been unexplained declines in honey bees in Europe and the United States (Goulson et al., 2015). This phenomenon known as Colony Collapse Disorder (CCD) is believed to be caused by various factors including parasites, pesticides and food shortages (Goulson et al., 2015) and has led to global concern and interest in honey bees.

Despite this, the number of honey bee colonies in New Zealand is rapidly increasing (Brown et al., 2018). The increased colony growth is driven by the Manuka honey industry, the price premiums mean the majority of New Zealand Apiarists rely on honey production as their main income (Brown et al., 2018), this contrasts with the rest of the world where honey production income is secondary to income from crop pollination (Rucker et al., 2012). The increase in economic value of honey is driving the increase in beekeeping in New Zealand, bee numbers have doubled in the last seven years, however the number of flowers available has not, and as a result some sites are becoming overcrowded leading to malnutrition, starvation, lower honey yields and increased spread of disease (Brown et al., 2018). Surprisingly 93% of the beekeeping operations in New Zealand are small and non-commercial and these operations experience higher colony loss than commercial operations (Brown et al., 2018). With the increased interest among urban residents to keep honey bees within their yard, residents and landscape architects may be uncertain about how to design in support of honey bees and to decrease honey bee mortality rates in hobbyist beekeeping operations. This paper critically reviews internationally peer reviewed literature to identify the habitat needs of honey bees in New Zealand's urban residential areas.

Needs of Honey Bees

Nesting

Available nesting sites affect bee abundance in urban areas, a review of the literature by Hernandez et al., (2009) found in most studies the abundance of cavity nesting bees such as honey bees is higher in urban areas compared with the number of ground nesting bees. Honey bees are cavity nesting. Colonies choose nesting sites based on attributes which promote colony success, such as cavity volume and entrance size (Nevai et al., 2010), allowing maximum shelter and protection from predators (Passino et al., 2008). In a natural setting appropriate nesting sites are likely to be cavities in trees (Nevai et al., 2010; Passino et al., 2008). In an urban area honey bees are likely to nest in manmade hives, a study by

Ratnieks (2014b) amalgamated plant genus listed in books promoting pollinator friendly gardens with relevant academic literature to find nineteen recommend plant genus including; Oregano *Origanum*, goldenrods *Solidago, Aster,* Californian lilacs *Ceanothus*, Knapweeds *Centaurea*, wallfowers *Erysimum*, lavender *Lavandula*, apple trees *Malus*, stone fruit trees *Prunus*, *Scabiosa*, milfoil *Achillea, Cotoneaster, Dipsacus, Eschscholtzia*, bonesets *Eupatorium*, ivy *Hedera*, sunflowers *Helianthus*, *Lobularia* and *Rubus*. Piroux et al. (2014) found palm trees *Arecaceae*, evening primrose *Onagraceae* and honeysuckle *Lonicera* are also proven to be attractive to pollinators, this study included honey bees but also looked at a wide range of other pollinating insects, attractiveness of each plant to may vary for each pollinator. In another study Martins, Gonzalez, and Lechowicz (2017) noted that *Daucus carrota, Eutrochium maculatum, Hypericum kalmianum, Solidago and Thymus serpyllum* all encourages high bee diversity. These findings support honey bees being a generalist species which gather nectar and pollen from a wide range of flora.

In contrast many ornamental plants are not attractive to honey bees and there can be large variations in attractiveness between different varieties of the same species. Garbuzov et al., (2014) studied dahlias and discovered that open dahlia varieties were 20 times more attractive to bees than closed dahlia varieties, this study only looked at one garden and therefore results should be interpreted with caution, however the results suggest that accessibility of nectar and pollen is an important factor. A similar experiment focusing on lavender found that Lavandula x intermedia was significantly more attractive to bees than other lavender varieties (Garbuzov et al., 2013). These findings suggest honey bees may select flowers based on quality, quantity and accessibility of pollen and nectar.

In highly built up urban areas, green roofs have been identified as important sites for bee conservation because they provide potential habitat for honey bees to forage and collect food (Garbuzov et al., 2015; Senapathi et al., 2017; Tonietto et al., 2011). Honey bees have the ability to forage vertically collecting from floral resources both at ground level and on rooftops (Braaker et al., 2014), they have been recorded on green roofs of buildings ranging in height from 1 to 12 stories (Kratschmer et al., 2018; Ksiazek et al., 2018). Green roofs may be retrofitted to existing buildings and help with storm water runoff, improving temperature regulation and mitigating the urban heat island effect (Oberndorfer et al., 2007). Increasing the number of green roofs will provide foraging habitat for urban honey bees while simultaneously contributing to wider socio-economic benefits (MacIvor et al., 2015).

Water

A fresh water supply is essential for healthy honey bee colonies, worker bees collect water from open water sources bringing it back to the hive for consumption and temperature control (Kühnholz & Seeley, 1997). One study suggests honey bees are likely to frequent easily accessible water sources such as storm water management ponds, street drainage, puddles, fountains and potted plants, unfortunately these may be contaminated (Johnson & Pettis, 2014). Further research is required on water supply for urban bees to establish if safe water is available for honey bees, however it is advised that apiarists provide a clean water supply near hives to ensure a colonies are not contaminated (Johnson & Pettis, 2014).

Climate

Studies found a correlation between bee abundance and sun exposure suggesting honey bees prefer sunny areas (Makinson et al., 2017; Matteson & Langellotto, 2010), but there is little in the literature on how other climatic conditions effect honey bees. Despite this, in studies where honey bees were sampled, the ideal conditions for sampling were identified as little or no wind, warm temperatures above 20°C and sunshine (Banaszak-Cibicka & Żmihorski, 2012; Garbuzov & Ratnieks, 2014a; Garbuzov et al., 2014), suggesting honey bees are most active in these conditions. A study on overwintering colony loss in New Zealand suggested extreme climatic conditions have little impact on bee colonies, as the majority of the country does not experience seasonal temperature variations to the same extent as large continents (Brown et al., 2018). Further research is required to establish how climate affects honey bees in urban residential areas.

Supportive yard management

Humans are the driving force behind urban landscape change, therefore the decisions they make impact all ecological systems functioning within the cities. Many believe that there is a positive correlation between ecological quality and good quality aesthetics (Gobster et al., 2007), however the needs of honey bees and residents aesthetic preferences are not always aligned. Understanding people's perception of beauty in a landscape is central to creating support for ecologically motivated landscape change (Gobster et al., 2007). Issues arise for the future of bees in an urban environment when there is a conflict between the aesthetic goals and the ecological goals within a particular landscape (Gobster et al., 2007). While campaigns to increase public awareness of ecological issues have helped increase ecological knowledge in recent times, this knowledge does not necessarily mean the public is able to see beauty in ecologically beneficial landscapes (Gobster et al., 2007). This can be seen in residential gardens where many ornamental plants are grown for their aesthetic value and yet they are not attractive to honey bees (Garbuzov et al., 2014). On the other hand plants which encourage high bee diversity such as wild carrot *Daucus carota* and goldenrod *Solidago* (Martins et al., 2017) are often aesthetically unappealing in residential gardens. Gobster et al. (2007) recognize the need for decision making strategies which better align human values and ecological goals resulting in landscapes which are both aesthetically pleasing and able to provide valuable food sources and habitat for species such as honey bees.

Lawns

Urban green spaces including residential lawns provide valuable pollen and nectar resources for bees in an urban environment (Baldock et al., 2015; Hinners et al., 2012; Lerman & Milam, 2016). To what extent a lawn is able to support honey bees depends largely on the management choices of the resident. Research show that frequency of lawn mowing can alter bee abundance, reducing mowing regimes has been found to increase pollinator numbers (Senapathi et al., 2017). Prairies or grasslands which are largely unmaintained contain more floral resources and therefore have much higher pollen and nectar resources and foraging habitat for bees than manicured lawn or turf (Bennett et al., 2014). In contrast a study by Lerman et al. (2018) found that while lawns mowed every three weeks had significantly higher floral abundance, lawns mowed every two weeks had a high bee abundance. These results may be explained by an abundance of flowers surrounding the lawn which are favourable over lawn flowers such as dandelions and white clover, the food source within a lawn (Bennett et al., 2014; Hicks et al., 2016; Lerman & Milam, 2016).

Disturbances

Hernandez et al. (2009) hypothesize human disturbances such as pollutants, foot traffic and pesticides may have negative effects on urban honey bee colonies, however with the exception of pesticides little academic research has been done in this area. Alternatively Winfree et al. (2009) suggest honey bee abundance is not affected by anthropogenic disturbances and they may thrive in a moderately human disturbed landscape providing a 'rescue effect' for plants which depend on pollination.

With the rise of CCD extensive research has been carried out to establish the effects of pesticides on honey bees. Within the body of literature there is controversy over the connection between pesticides and pollinator declines. Many studies have found that the use of pesticides, in particular neonicotinoids, adversely affect honey bee health and many researchers believe there is a clear link between neonicotinoids and declining honey bee populations in Europe and the United States (Burkle et al., 2013; Piroux et al., 2014; Potts et al., 2010). However there is uncertainty and debate among academics about the extent of the impact. Gill et al. (2012) claim there is a link between pesticide use and subtle or sub lethal effects on individual behaviour such as diminished foraging performance and pollen collecting ability, however the effects on the entire colony are yet to be shown. In contrast Henry et al. (2012) found neonicotinoids have a lethal effect on individuals causing homing failure and therefore a high mortality rate. There is also evidence of sub lethal effects on colonies such as diminished reproductive success affecting colony growth (Henry et al., 2012). This is contrary to Wood et al. (2018) finding brood area is not sensitive to sub lethal effects of neonicotinoids. Much of the research focuses on the agricultural sector where pesticides are widely used. Further research is required to determine the effects of pesticides use in an urban environment. One study found honey bee health may be adversely affected if water sources are contaminated, after testing urban water sources for traces of neonicotinoids and finding a puddle in a nursery contained enough to kill a small percentage of the nearby bee population. Sub lethal doses were also found in other urban water sources (Johnson & Pettis, 2014).

Connectivity between habitats

Urban residential areas are more attractive to honey bees than highly built up areas (Fetridge et al., 2008). As urbanization increases, in particular the growth of concrete, built structures and impervious surfaces, the abundance of honey bees decreases (Banaszak-Cibicka et al., 2016; Martins et al., 2017; Plascencia & Philpott, 2017). This may be because foraging habitat becomes more widely dispersed (Plascencia & Philpott, 2017) and isolated gardens and green spaces are unable to provide the habitat needed to support large numbers of pollinators (Philpott et al., 2014).

Increases in urbanization are driven by the growing world population and cities are rapidly expanding to provide for human needs (Barnosky et al., 2012; Leong et al., 2016). In many areas natural and semi natural habitats are being replaced by built structures and this is regarded as a primary reason for pollinator declines (Martins et al., 2017; Winfree et al., 2009). However honey bees have the ability adapt to the fragmented, patchy urban environment because they are floral generalists and have a large foraging range, they are less sensitive to land use changes than many smaller bee species (Plascencia & Philpott, 2017). In urban areas fragmentation decreases the abundance of honey bees, however the decline is not significant until there is very little or no natural habitat remaining (Winfree et al., 2009). It is also noted that garden size and distance to remnant natural habitat has little effect on bee populations in highly urbanized areas (Makinson et al., 2017), therefore improving the value of small existing urban habitats and incorporating new green spaces into the built environment will help to conserve and restore urban honey bee populations (Baldock et al., 2015; Bennett et al., 2014). Appropriate honey bee habitat may include gardens which provide an abundance of flowers for bees (Plascencia & Philpott, 2017; Quistberg et al., 2016), as well as other green spaces such as lawn, parks and grasslands which also provide foraging habitat (Bennett et al., 2014).

Honey bees are larger in size than many other bee species, their increased size allows them to forage larger distances (Martins et al., 2017) and capitalise on widespread food sources (Plascencia & Philpott, 2017). Because honey bees have the flexibility to adjust foraging distance, urbanisation has little effect on the visitation rates of honey bees to desirable food sources (Martins et al., 2017). Garbuzov et al. (2015) studied the foraging patterns of honey bees in Brighton, UK and found that the foraging distances in the urban environment ranged between 461m and 1229m. Despite this study being specific to Brighton and not directly related to New Zealand cities, the lower foraging distance suggests that cities can provide ample food sources for urban honey bees.

Conclusion

It is important urban habitat for honey bees is protected and enhanced to ensure the longevity of these integral insects. Honey bees provide humans with two key services; firstly honey production contributes greatly to the New Zealand economy through exports for consumption, cosmetics and medical uses (Brown et al., 2018), secondly pollination services ensure the success of our edible crops, and allow residential gardens to flourish. Globally honey bee populations are under threat (Potts et al., 2010), however domestically managed honey bee numbers continues to rise while simultaneously urban areas continue to expand and honey bee habitat is diminished. As food resources become more scarce hives suffer and the risk of colony loss increases (Brown et al., 2018). Creating habitats to support honey bees and reducing threats such as pesticides should increase the survival rate of honey bee colonies in New Zealand leading to increased honey production and pollination services.

Interest in honey bee health has grown in the last 12 years, however much of the research focuses on honey bees in relation to agricultural and commercial apiculture. Further research is required into the effects of anthropogenic disturbances on honey bee populations in urban residential areas. Studies which have been conducted in an urban environment suggest honey bees are able to adapt and thrive if provided with a sufficient food source, clean water, nesting sites, limited disturbances and habitat connectivity. Small fragmented green spaces within the urban matrix are able to support large numbers of honey bees if designed and managed appropriately. Despite this there is a lack of consolidated information available to residents encouraging enhancement of backyards and gardens to support honey bees. There is a need for comprehensive and easily accessible guidelines allowing residents, landscape architects and planners to enhance and create green space to support urban honey bee.

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