What's all the buzz?

Managing competing interests in native floral resources to develop Australia's commercial beekeeping industry

A case study of Western Australian commercial beekeeper resource insecurity on public lands in the southwest region

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Forward

Honey bees are livestock that require year round access to flowers providing nectar and pollen resources necessary for keeping colonies alive and reproducing. Commercial beekeepers have developed a system of hive migration across flowering events in the Australian bush to meet the demand for bee nutrition, honey production, and to provide pollination services to agriculture. Given the quantum of land required to service year-round flower production for commercial quantities of hives, it is rare for a beekeeper to own or manage the majority of floral resources they access. To meet forage demand, beekeepers generally rely on a mix of public apiary sites accessing native vegetation managed by the state government, or private sites on or adjacent to farmland. Each scenario presents the challenge of dealing with competing interests in forage resources that beekeepers re only. This competition then contributes to both individual and collective resource insecurity.

This project focuses on public apiary sites where high-value honey from Western Australia is produced. Native flowering resources suitable for bee forage are managed by the Western Australian state government and they are challenged with meeting a variety of interests ranging from forestry, mining, ecotourism and flora conservation. Beekeeper livelihoods are particularly sensitive to activities that impact the quality and quantity of forage at a site as well as the ability to secure access to native flora on a year-round basis. This project explores the dynamic nature of beekeeper resource insecurity and explores the complexities of challenges faced by the industry. Through the research presented in this project, a novel method of engagement was developed involving beekeepers and resource managers in pertinent conversations whilst in the field surrounded by the resource they either manage or access for their livelihood. In moving the issue of beekeeper resource insecurity beyond conversations over access alone, this project offers a new and novel approach to reframing beekeeper interests in stewardship for a healthy, resilient, native ecosystem.

Dr Liz Barbour
CEO

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About the Authors

Linda Wilson has dedicated her career to examining environmental management issues from a variety of perspectives which motivates her to critically examine the root causes of contemporary land management challenges. She received a Bachelor of Science in Natural Resource Management - Honours (1st class) and Masters of Business Administration from University of Western Australia. She has worked with farming communities in the Great Southern (WA) on Landcare and indigenous communities in Vanuatu on Eco-forestry projects. Her time at Australian Wildlife Conservancy was dedicated to addressing biodiversity decline through science-based land management. She has also worked in the renewable energy sector installing wave, solar and battery projects in remote locations in WA. Her interdisciplinary academic interests and practical experiences provide a multi-faceted frame to research society's sustainability challenges.

Clare M Mouat is a Senior Lecturer at Massey University, New Zealand and an Honorary Research Fellow at The University of Western Australia (UWA). Her primary expertise is in community, governance, and planning regimes. Clare's research agenda examines interdependencies, power, critical infrastructures, health and wellbeing, as well as key reforms and innovations in the governance and planning of communities, cities, and regions. Specifically, she examines the existing and desired functional governance frameworks for (more-than) human flourishing places: from local to planetary scale to outer space. To this end, her research weaves different disciplines, theories, collaborative energies, and lived experiences for addressing the 21st-century challenges of urbanism, crises (climate and health), and democracy. Consequently – through teaching, research, and community engagement – her work shapes and informs policy, law, and scholarship across Australasia, the OECD, and Global South: including planning, multi-lot living, street verge policy, and resource management. Clare became the principal supervisor of this project while she was lecturing at UWA. The CRC Honey Bee Products PhD project enriches her expertise in beekeeping: building from her experience in a WA commercial beekeeping enterprise, her qualification as a Queen Bee breeder, and wider collaboration with the CRC contributors and beekeeping communities internationally. From her award-winning PhD to TEDxUWA salon talk, state public debates, and international invitations to engage with her critical scholarship, Clare's work joins with those who seek pathways to regenerative governance and equitable well-being that affects each of us, our families, and seven billion of our closest neighbours.

Bryan Boruff is an Associate Professor in the UWA School of Agriculture and Environment at The University of Western Australia (UWA). Bryan's expertise is in the application of Geographic Information Systems (GIS) and Remote Sensing technologies to the study of environmental hazards. Over the past decade, Bryan's research interests have expanded to encompass a range of environmental management issues including renewable energy and agricultural production, population health, sustainable livelihoods and the development of spatially enabled eResearch tools. He has extensive experience working in developing nations in multidisciplinary settings with academic, private and government stakeholders.

Acknowledgments

- Noongar elders past, present and emerging, who are the traditional custodians of the southwest of Western Australia where this research was conducted.
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- Bee Industry Council of Western Australia (BICWA)
- Cooperative Research Centre for Honey Bee Products and CEO Liz Barbour
- Staff from the Department of Biodiversity Conservation and Attractions (DBCA), University of Western Australia (UWA), Geography Department, research assistants

Abbreviations

BICWA	Bee Industry Council of Western Australia
CRC HBP	Cooperative Research Centre for Honey Bee Products
DBCA	Department of Biodiversity Conservation and Attractions
DPIRD	Department of Primary Industries for Regional Development
FMP	Forest Management Plan
GIS	Geographic Information System
GWW	Great Western Woodlands
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
NRM	Natural resource management
RFA	Regional Forest Agreements
SES	Social-ecological systems
SWAFR	Southwest Australian Floristic Region
WA	Western Australia

Executive Summary

Beekeeper resource insecurity is a growing concern for the industry. It is defined here as an individual or collective inability to maintain access to sufficient productive forage resources needed to sustain commercial beekeeping livelihoods. Migratory commercial beekeepers (beekeepers) rely on native melliferous floral resources (floral resources) on public land to produce the majority of Australia's commercial honey supply. Floral resources also perform the critical function of maintaining healthy honeybee colonies which are vital pollination services required by agriculture and horticultural industries. Beekeepers face resource insecurity as their overarching management challenge. Unlike the farming community, beekeepers lack the right or capacity to manage the forage resources they rely on, and those resources are significantly impacted by the established and emerging activities of numerous competing interests.

Resource insecurity is in part driven by the demand for greater access by newcomers to the beekeeping industry, increasing pollination service requirements and increasing demand and price paid for premium honey. Approaches to addressing resource insecurity have tended to focus on the barriers to maintaining or gaining access to public resources. However, within policy settings, access to floral resources for use by beekeepers is under-prioritised compared to competing uses (including mining, forestry, conservation and tourism/recreation). The problem with an 'access-focused' approach to resource insecurity is that it does not specifically address the concerning trend of declining quality and quantity of forage resources due to management approaches, competing interests, and climate change. This project offered a novel relational approach to the problem using a case study of Western Australia's commercial beekeeping community, operating on public lands in the southwest region of Western Australia. Using a transdisciplinary sustainability research approach, the objective was to highlight the relationship between beekeepers and their resources, resource managers, competing interests and drivers of environmental change.

To answer the fundamental question of what caused resource insecurity for beekeepers, this project used a multi-method qualitative research approach. Research participants included 19 commercial beekeepers, 6 government officials and 4 industry/academic experts. Data were collected from 18 individual interviews and 97 interview/focus groups conducted in field locations across various types of native floral resources relied upon by beekeepers, namely forests, woodlands and coastal habitats. Primary data was triangulated with secondary sources using a multi-evidence-based approach to build a rich picture of how competing interests influence the management of public lands and how those interests can adversely affect environmental values on apiary sites ('apiary site values'). 'Apiary site values' refers to the qualities and attributes that a beekeeper monitors and assesses as an indicator of the current and future productivity of a site.

The relational research approach required an innovative method to address the power asymmetry between beekeepers and state government agencies responsible for managing floral resources on public land. To this end, B-harmony was developed as a new 'stakeholder engagement' method for addressing issues of natural resource access and use. The approach uses 'place' to contextualise

conversations over contested topics associated with environmental management. A key outcome of the method is the ability to explore conflicting values and knowledge whilst capturing stakeholder interactions to develop a rich picture of the socio-ecological system.

Through analysis of data collected in the field with beekeepers and natural resource managers, the project identified that:

1. we need a better understanding of resource insecurity and its impacts on sustainable livelihoods over time. Specifically, beekeeper resource insecurity is associated with:
    a. impacts on the quality, quantity and access to natural resources often resulting from management approaches and competing interests. Climate change is exacerbating the cumulative impacts of anthropogenic disturbances on the environmental 'values' which drive the productivity of apiary sites.
    b. a lack of understanding about how beekeeper livelihoods are conducted, the ecological 'values' they depend on, the knowledge they generate through practice and how apiary site 'values' are affected by competing interests that impact beekeepers' ability to effectively engage with land managers and work towards improving these relationships.
2. developing pathways to improve resource security and environmental outcomes requires a collaborative relationship between the industry and resource managers underpinned by stewardship values.
3. using the B-harmony approach models interactions that underpin the problem reframing and help develop the necessary relationships to co-produce an enduring solution. Although this was modelled in the Western Australian context it has values in other jurisdictions and contexts.

A key message from this research is that natural resource managers and industries that depend on these resources should align objectives to develop collaborative partnerships that foster environmental stewardship of biodiverse environments for mutual gain.

How to read this report

This report is a summary of insights from a larger PhD project that is in progress. This report is to outline:

- the research problem
- the research approaches
- methods of data collection
- preliminary insights from analysis and results

Substantive results are provided in the thesis currently in preparation.

The Academic and Industry Outputs section highlights deliverables from the project including infographics, which are high-level summaries of the results. The infographics are utilised along with supporting commentary in the Results section of this report.

Academic outputs

PhD Thesis:

Towards Environmental Stewardship: addressing the challenges of commercial beekeeper resource insecurity on public lands in the Southwest Floristic Region of Western Australia

Conference Talks:

- EcoPeople Symposium: Water Communities Symposium – 28 October 2022: *"Importance of water for generating apiary site value and sustaining beekeeping livelihoods"*

- Fourth Australian Honeybee Congress – 10 June 2022: *"The future of land management… with beekeepers in mind"*

- Australasian Honey Bee Conference – 30 June 2021: *"In the eye of the bee-holder: sharing perspectives on beekeeper resource insecurity"*

- South Australian Apiarist Association Conference Talk – 11 June 2019: *"From cross-talk to collaboration… co-production of knowledge to improve access for beekeepers to melliferous native flora in WA"*

- EcoPeople Symposium: Environment and Society Now – 31 October 2019: *"From Cross-talk to collaboration: Sustainability research to secure natural resources. A case study of the Western Australian Beekeeping Industry"*

Research Poster:

- PSA Research Week 2021: *"Buzz Off? A historical analysis of the emergence of commercial beekeeper resource insecurity on public lands in the south-west of WA"*

Industry outputs

Toolkit

- B-Harmony Stakeholder Engagement Toolkit *(under development)*

CRCHBP Case Study Flyer

- B-harmony: engaging for environmental stewardship

B-harmony: engaging for environmental stewardship

B-harmony is an innovative field-based stakeholder engagement tool to support beekeeper resource security. It provides a protocol for constructive engagement between industry, scientists and resource managers in environmental stewardship.

Stakeholder engagement, including meetings, workshops and reports, allow for limited understanding of people's experiences and needs. Misunderstandings can lead to conflict over resource allocation, use and management. Effective engagement can foster collaborative relationships that promote stewardship of healthy, biodiverse ecosystems.

Commercial beekeepers rely on the forests on public lands to sustain bee health for pollination services and to produce honey. However, beekeepers don't manage these resources, and competing interests and management decisions can impact their livelihoods. Beekeepers have experienced the declining health of plant communities caused by human activities and climate change. This resource loss, and reduced accessibility to high-quality forage, has led to resource insecurity, challenges to sustained bee health, and reduced honey production.

B-harmony is a new facilitation process that builds relationships between resource users and managers.

The CRC for Honey Bee Products has developed B-harmony to bring together participants from industry, government and science to co-produce knowledge about beekeeper resource insecurity.

CRCHBP

collaborate

decision support

environmental stewardship

Research to underpin B-harmony was conducted in south-west Western Australia's floristic region with commercial beekeepers operating from apiary sites on public lands. The research focused on the relationship between beekeepers and the state's environmental agencies, which manage public land.

B-harmony is a protocol that bridges ecological knowledge and differing perspectives.

CRC researchers led in-field focus groups to explore environmental challenges at affected locations. Using the B-harmony protocol, facilitated discussions were conducted at locations of importance to help participants increase their knowledge about threats and potential solutions. Participants moved from positions of conflict to imagining opportunities for collaboration and knowledge sharing.

As well as a protocol for stakeholder engagement, B-harmony gives a voice to the environment. It does this by offering a forum for a diverse group of experts to gather and share knowledge in a way that is inclusive of those from outside the scientific community.

B-harmony is a comprehensive, theory-informed, practical guide for engaging with stakeholders' values and knowledge. The method of engagement suits people motivated by environmental stewardship.

The CRC produced B-harmony in partnership with the beekeeping community. The approach will be helpful wherever natural resource managers seek to involve diverse stakeholder perspectives and knowledge to generate stewardship partnerships with industry and the community.

CRC PhD student, Linda Wilson, using the B-harmony engagement tool she developed to introduce beekeeper resource issues to other stakeholders and managers of the forest.

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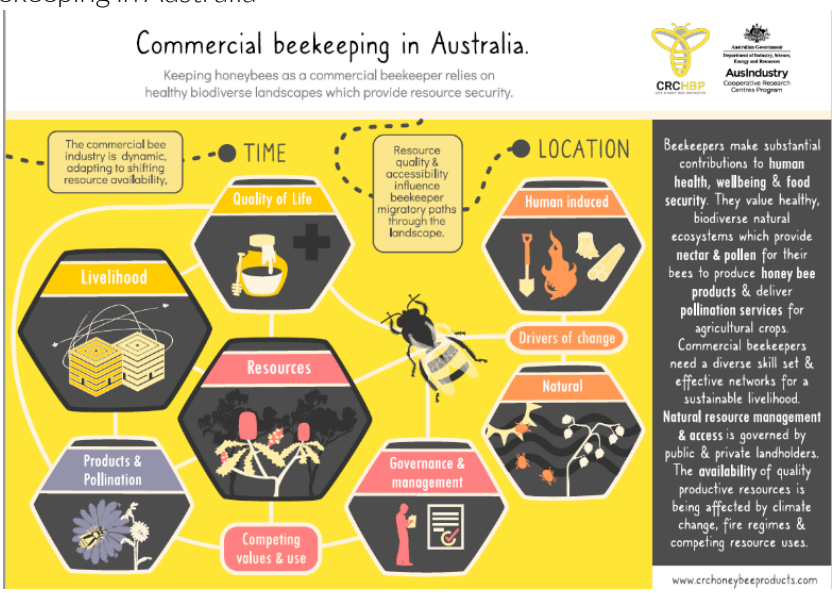
Australian Government Department of Industry, Science, Energy and Resources

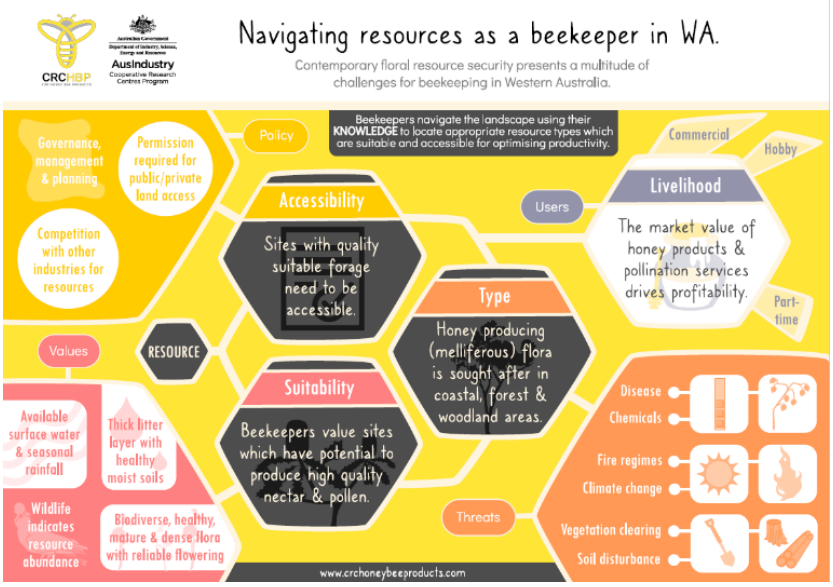
AusIndustry Cooperative Research Centres Program

Infographics (of key insights from Results)

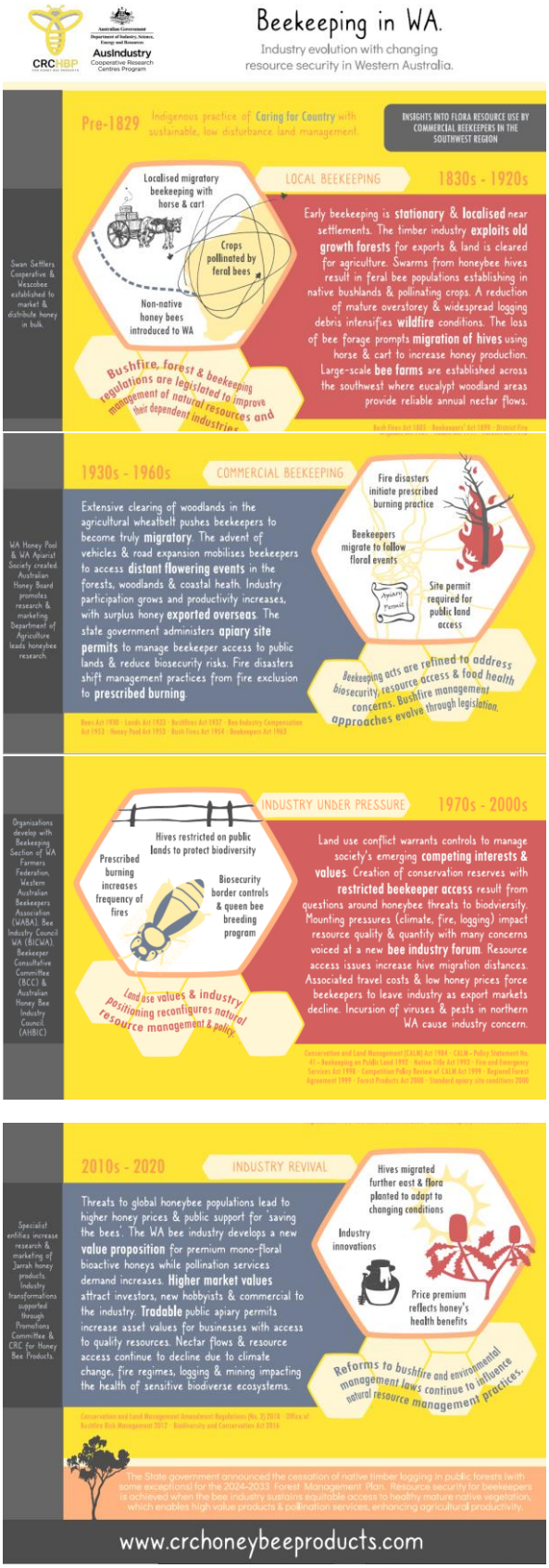
- Commercial Beekeeping in Australia



- Navigating resources as a beekeeper in WA



- Beekeeping in WA



Introduction

Australian commercial migratory beekeepers have built successful multi-generational businesses utilising the unique reproductive attributes of native floral resources such as honeybee (*Apis mellifera*) forage. By gaining and maintaining access to bee forage resources, beekeepers make use of flowering opportunities that provide nectar and pollen, which bees convert to clean, green, authentic honey and related products highly valued in domestic and international markets. Commercial migratory beekeepers operate within complex social-ecological systems shifting bees between natural and agricultural landscapes where floral resources are managed by either public or private land managers (Patel, Biggs, et al., 2020). Due to a 200-year history of native vegetation clearing, the majority of commercially produced honey comes from apiary sites on public land managed by environmental agencies (Somerville, 1998). These agencies manage vast areas of native bushland to satisfy multiple societal values with limited budgets and shifting state and federal policy settings. These competing interests include, but are not limited to, timber production, mining, bushfire protection, tourism, recreation, conservation and non-timber forest products like firewood and wildflower picking (Conservation Commission of Western Australia, 2013).

It has been observed that competing uses and natural resource management activities impact beekeepers' ability to effectively utilise the resources they depend on to maintain their livelihoods. Over the last four decades, when provided the opportunity, commercial beekeepers have raised their concerns about their ability to maintain access to native floral resources and the impacts of natural resource management and competing interests on the quality of floral resources (Blyth, 1987; House of Representatives Standing Committee on Primary Industries and Resources, 2008). In Australia, asymmetric power relations between the beekeeping industry and competing interests mean that a beekeeper's environmental 'values' often go unrecognised within associated policies and decision-making frameworks or are not prioritised in natural resource management planning. Significant tension exists between commercial beekeepers, land managers and competing interests due to a reduction in the quantity and quality of melliferous honey-producing) native floral resources across WA.

Resource insecurity due to the activities of competing interests and climate change presents a significant threat to the industry's future capacity to produce high-value honeybee products and pollination services to meet the demands of over 30 associated industries. The imminent threat of *Varroa destructor* and its likely impact on the industry including a significant reduction in the feral bee population (which provides free pollination services for agriculture), only reinforces the need to value melliferous natural resources for their ability to support commercial apiaries. However, at this stage, resource insecurity remains a significant threat due to the negligible influence beekeepers have on the management of resources they rely on to sustain their livelihoods. Resource insecurity is defined here as a commercial beekeeper's inability to gain and maintain access to sufficient quality and quantity of (re)productive floral resources to support sustainable livelihoods due to the impacts of competing interests and climate change.

The commercial beekeeping industry's fortunes reflect changing social, economic and ecological conditions; however, research into this complex adaptive system has been diverse yet sporadic. Since the 1980s, numerous academic researchers, government enquiries and stakeholder engagements

have sought to address beekeeper resource insecurity using a variety of foci including risks to food security (House of Representatives Standing Committee on Primary Industries and Resources, 2008), the economic consequences of declining access to public natural resources (Clarke, 2020; Gill, 1996), and compatibility of land management practices with beekeeping (Blyth, 1987; Salvin, 2015). Through the 1990s and early 2000s, the Rural Industries Research and Development Commission (RIRDC, now AgriFutures Australia) developed a floral resource database for each state (e.g. NSW (Somerville et al., 2000)). However, by and large, the outcomes have failed to highlight the profound connection that exists between the beekeeping industry and the reproductive health of the environment they depend upon.

A major challenge faced by researchers is the lack of quantitative data produced by the honeybee industry. This deficit makes it challenging to represent the dynamism of beekeeper resource use and the impact of competing resource uses for government to make effective policy decisions. It also makes it challenging for the industry to demonstrate ways in which historic and contemporary natural resource management practices negatively impact their productivity. For instance, an attempt to characterise the WA industry through surveys has occurred twice in the past 30 years (Day & White, 2022; Manning, 1992) but it is difficult using these methods to truly reflect the dynamic attributes of the industry and its resource use. The relationship between the industry and government policy makers around resource security has been challenging to manage in part because of the difficulty of developing and communicating a clear cohesive message about the complexity of the system they operate within; including the influence of competing interests. This difficulty in communication is labelled 'cross-talk' by this project because the industry and the resource manager appear unable to communicate and move forward constructively due to differing views on certain issues where arguably synergistic objectives exist.

The research objective for this project was to increase understanding of competing interests in managing honeybee hive sites in the southwest region of Western Australia. The original objective recognised a key tension between beekeepers and state government agencies. Beekeepers were frustrated at resource insecurity threatening their livelihoods and state government agencies had a lack of understanding of the nature and possible resolutions to beekeeper concerns. This tension was compounded by the influence of well-established competing interests on the state's natural resource management. Consequently, the project focused on honeybee hive sites (apiary sites) on public lands and the relationship between beekeepers and state land managers. The project developed a case study to recognise and communicate the impacts of competing interests by understanding the relationship between beekeepers and floral resources. The project did this by:

- characterising the contemporary beekeeping industry (including resources and practices) and competing interests in relation to resource security on public lands of the southwest of WA
- exploring how the industry could better engage with land managers using notions of stewardship to:
  - contribute to a sustainable future for native bushlands, wildlife, and farming communities
  - promote a healthy commercial beekeeping industry.

Evidence was gathered by engaging with commercial beekeepers, government officials, and academics in interviews and focus groups. This primary data was combined with secondary sources of evidence to develop a conceptual framework for the case study. The framework organised splintered information into a cohesive narrative of how commercial migratory beekeepers operate in Western

Australia, the importance of their association with floral resources, and the impact competing interests and climate change are having on the 'value' of their apiary sites.

The toolkit *B-harmony* emerged as a key industry output from this project. It developed a technique for facilitating interactions between groups of stakeholders in the field to explore areas of common and competing environmental values. This toolkit has broader application to any range of natural resource management situations where resource users and resource managers have values or knowledge about the environment that result in conflict over resource access and use. The substantive results from this research project are provided in a PhD thesis titled*: Towards Environmental Stewardship: addressing the challenges of commercial beekeeper resource insecurity on public lands in the southwest of Western Australia* (working title). This project offers a useful framework for developing constructive relationships between beekeepers and the state government. The project engaged both parties in generating a mutual understanding of environmental values required to (1) secure resources for the industry and (2) promote healthy productive environments of benefit to bees and the broader native flora and fauna that rely on these resources. It therefore has the potential to provide significant societal benefit through the enhancement of both food security, and environmental and human health.

CRC Objective

To increase understanding of competing interests in managing honeybee hive sites in the southwest region of Western Australia.

Impact

Informs the honeybee industry agenda to identify and work towards a 'license to operate' across native bushlands and to directly contribute to natural resource management outcomes that support the honeybee industry and healthy bush.

Output

This project will contribute to the following Outputs as stated in the Funding Agreement:

(1.2) Social, political and ecological barriers to current and future hive site accessibility are identified (license to operate).

Research Approvals

Approval for this research was provided by the UWA Ethics committee - RA 4 20 5932.

Fieldwork approval was provided by the UWA School of Agriculture and Environment.

Project Activities

The following is founded on theoretical foundations explored in greater detail in the forthcoming thesis. Here, the research approach and methodology are explained to highlight the innovation and significance of the research. An overview of the academic framing of the research is followed by a detailed discussion of the methods providing the primary substance of this report.

Research Approach: from cross-talk to collaboration

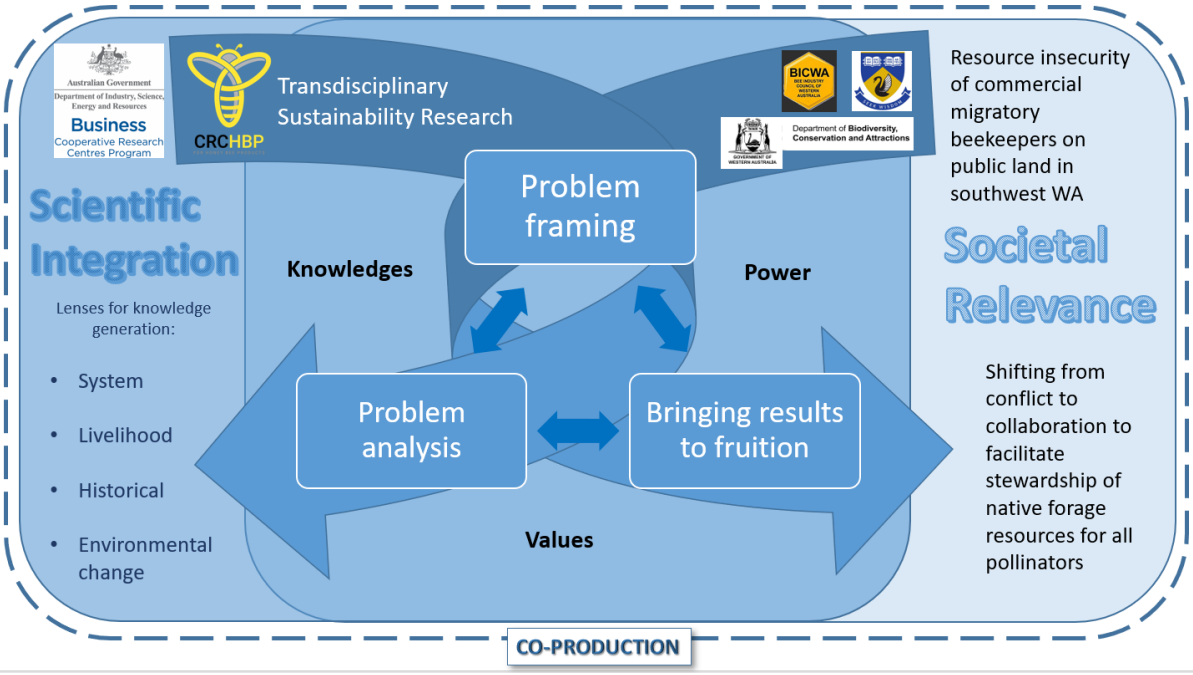


Figure 1: Research approach to Beekeeper Resource Insecurity: orienting the scope and nature of the research within CRC HBP

Figure 1 illustrates the research approach used to guide this project. First, key stakeholders (BICWA and DBCA) were brought together with academia (UWA) to frame the research problem(s) ('Problem Framing'). The CRC for Honey Bee Products then supported a transdisciplinary approach ('Transdisciplinary Sustainability Research') (Huutoniemi & Tapio, 2014) used to address the real world problem of beekeeper resource insecurity. A philosophy of knowledge 'Co-production' guided the development of the research design and methods (Wyborn, 2015). The research process itself provided an opportunity to develop a new understanding between key stakeholders (Tobias et al., 2019a). Through analysing the current beekeeper resource insecurity problem ('Problem Analysis'), the researcher generated four understandings of the situation based on (1) systems thinking, (2) a livelihood perspective, (3) historical change, and (4) environmental change. These findings provide new knowledge that can be further developed by stakeholders in the future ('Bringing Results to Fruition'). The process recognises that in researching real-world sustainability issues, the situation can be fluid and complex, hence multiple iterations of problem framing, data collection and analysis are often required to address problems of societal relevance. The research process itself aimed to contribute towards a relationship shift between stakeholders from that of misunderstanding and conflict ('cross talk') to a relationship of collaboration to protect native floral resources for multiple uses (Tobias et al., 2019b).

Research Design: generating evidence and relationships

The research design shown in Figure 2 demonstrates the relationship between the research objective, research questions, data collection, data analysis and results.

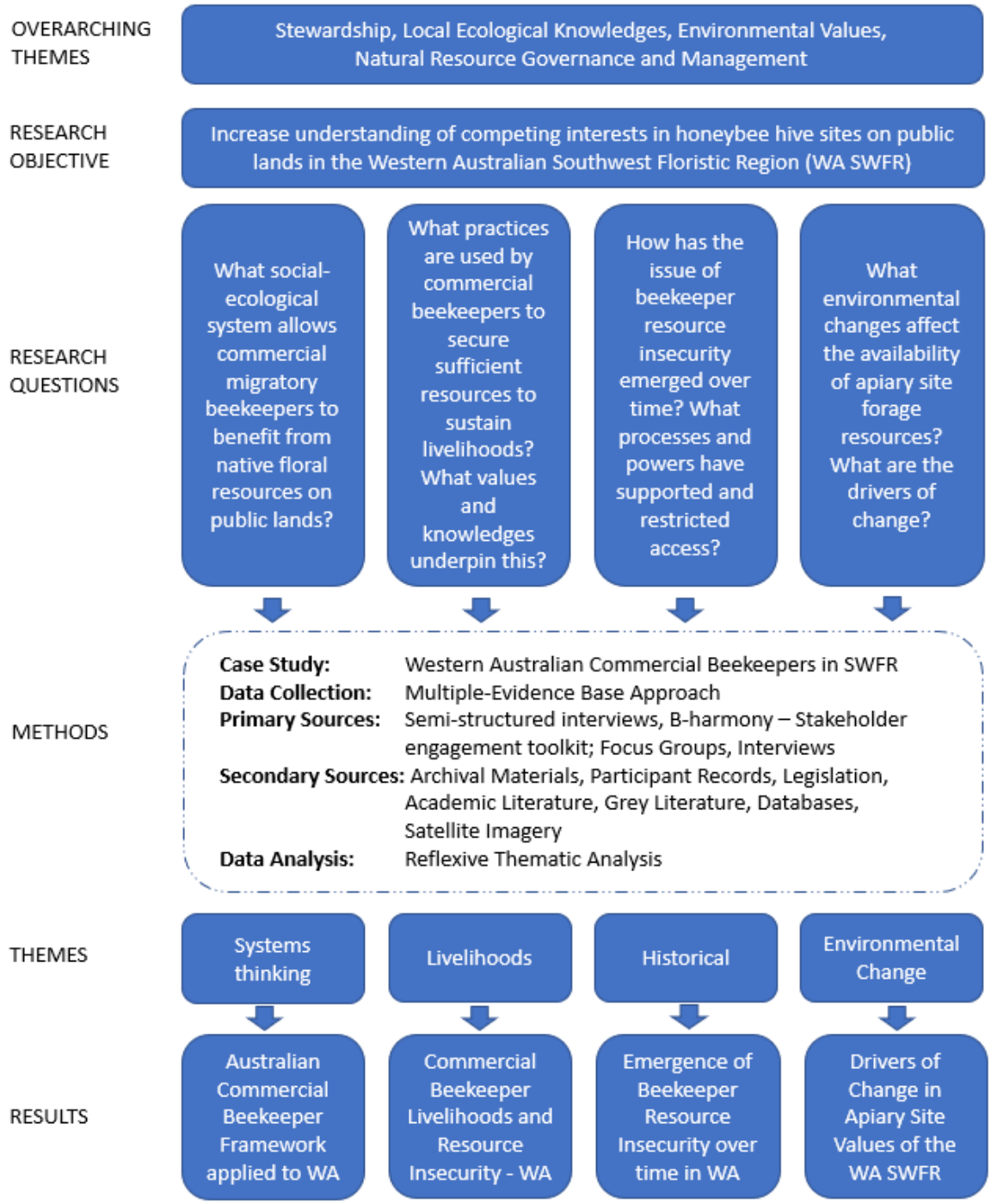


Figure 2: Research Design: developing the evidence base and relationships to reflect the dynamism of the industry

Research Method

Overview

This project explored the case study of Western Australia's commercial beekeepers operating across the southwest region of WA. It was enacted using the following methods of data collection and analysis. First, an outline of the geography of the case study and an explanation of how beekeeper resources are classified is provided, followed by a description of the development of '*B-harmony*' (used to facilitate focus group interactions in the field).

Case Study of Commercial Beekeeping in southwest WA

This project focused on commercial migratory beekeepers producing honey from native floral resources on public apiary (honeybee) sites across the southwest of Western Australia (WA). Forage resources on public land are managed by the state Department of Biodiversity of Conservation and Attractions (DBCA). DBCA manages public lands throughout WA for multiple values and purposes. They administer apiary site permits, which beekeepers use to access forage resources that are predominantly located on public land in the southwest region of the state. Whilst this research focuses on resource security as a contemporary issue, with primary data collected between 2019 and early 2021, the analysis also considers processes that were initiated as a result of settler colonisation (i.e. from early 1800s). This research was conducted in cooperation from the Bee Industry Council of Western Australia (BICWA) who are the peak industry body for beekeepers in WA, as well as DBCA.

The commercial beekeepers who participated in this case study operate within the naturally and socially constructed boundaries of the southwest region of WA. Beekeepers register their hives with the Department of Primary Industries for Regional Development (DPIRD). Although DPIRD consider commercial beekeepers as those that are registered and maintain more than 50 hives, in practice most full-time commercial beekeepers operate several hundred hives or more (Day & White, 2022). Many come from multi-generational beekeeping families and therefore have long associations with the industry and the environment in which they conduct their livelihoods. Most commercial operations migrate their bees for honey production. However, pollination services are increasing in demand, and are serving as a mode of entry for beekeepers who have limited access to native flora. Whilst there are only a few hundred commercial beekeepers in the region, and they are only a small proportion of the more than 4,400 beekeepers registered with DPIRD, they operate the vast majority of the 53,000 hives in the state (Department of Primary Industries and Regional Development, 2022).

Importance of nectar and pollen resources

Nectar, pollen and fruits are vital forage for a significant proportion of Australia's unique native fauna requiring a diverse habitat. A symbiotic relationship has developed over millions of years between native plants and animals resulting in plants offering copious quantities of energy-rich nutrition in the form of nectar to attract large vertebrates, such as birds, as pollinators (Orians & Milewski, 2007). Energy rich nectar fuels flight and provides birds the ability to transport pollen over long distances. They are encouraged to spread the pollen by the offer of nutritious rewards provided throughout the

landscape by successive flowering events (Low, 2014). Eucalypts and banksias in particular have used this strategy to increase the genetic diversity of their seed (Hopper, 2021). It was argued by Lowe (2014), that this relationship contributes to the diversity of eucalypts found today and has facilitated their adaptation over previous climate cycles. Confirmation of the global significance of this phenomenon is supported by the southwest of WA having the highest incidence of plants pollinated by birds and mammals on Earth (>15%). With more than a thousand flowering species visited by birds, it represents the highest density of this association on earth (Ford et al., 1979; Low, 2014). However a large pool of trees with staggered flowering is required to provide sufficient continuity of forage to sustain such large communities of birds (Low, 2014).

Whilst the reproductive evolution of myrtaceous (e.g. eucalypt) and proteaceous (e.g. banksia) species, and the unique biodiversity of Australian wildlife, has been identified by ecologists (Ford & Paton, 1986; Hopper, 2021; Low, 2014; Orians & Milewski, 2007; Wills et al., 1990), this dynamic and vital ecosystem functioning receives little attention in environmental management plans (Burrows et al., 2022; Conservation Commission of Western Australia, 2013). Further, despite decades of investigation into the pollination relationships between native flora and fauna (e.g. Ayre et al., 2020; Christensen, 1971; Delnevo et al., 2020; Ford et al., 1979), there remains a limited understanding of landscape patination of nectar events (Law et al., 2000); although recent advances in satellite technology offer intriguing possibilities for monitoring flowering events at this scale (Dixon et al., 2021). For instance, in describing flowering patterns of Eucalypts, Low (2014) identified that 'flowering is typically erratic, obliging many birds to wander the landscape, resulting in pollen from one stand travelling in many different directions'. To this end, this thesis argues that beekeepers have developed a rich understanding of this relationship as a bioindicator of ecosystem health.

Beekeeper local ecological knowledge and relationship with resource managers

Globally, commercial migratory beekeeping relies on gaining access to sufficient quantities of quality nectar and pollen forage resources to sustain honeybee colonies and produce surplus honey (Crane, 1999). A feature of the case study region, which makes it a veritable utopia for commercial beekeeping, is that the dominant flora has evolved to sporadically produce abundant quantities of nectar in a landscape, which also has diverse sources of pollen. Taking advantage of observable characteristics that indicate future flowering events is the basis upon which beekeepers successfully conduct their livelihoods. Phillips (2014) describes beekeepers as 'chasing honey' by following the nectar flows through the landscape. For many observers of the industry, 'the response of an apiarist to nature's ever changing conditions is an art rather than a science' (Smith, 1969, p. 1). Techniques using the latest technology, like satellites and drones are being developed to monitor flowering events (Dixon et al., 2021). Artificial intelligence is being used to try and identify key environmental factors that predict honey harvests (Campbell et al., 2020). However, these are unlikely to replace the knowledge generated by beekeepers through decades of on-ground observation, which is integral to a successful commercial business.

Honeybees themselves are recognised by the scientific community as useful bioindicators of environmental health (Bargańska et al., 2016; Couvillon & Ratnieks, 2015) and internationally beekeeper's local ecological knowledge has been found to mirror that of our scientific understanding of environmental changes (e.g. Coh-Martínez et al., 2019; Galbraith et al., 2017). Despite this, only a

limited number of Australian studies have utilised the knowledges of experienced beekeepers to better understand the flowering ecology of honey-producing flora [south-eastern Australia (Birtchnell & Gibson, 2006); southwest WA (Manning, 1992; Smith, 1969)].

A debate that has simmered for decades between the industry, state natural resource managers, the scientific community and conservationists is what tangible impact the introduced European honeybee (*Apis mellifera*) (either feral or managed populations) has had on the native environment. Of particular concern are the potential impacts on pollinator interactions and the overall reproductive success of native flora (see (Chapman & Oldroyd, 2019; Prendergast & Ollerton, 2021) for two sides of the debate). While this project does not engage in the debate, in part because in such a biodiverse environment it may be a question that can never be answered satisfactorily, it is still worth considering as an interaction that requires further investigation and one that can be informed by beekeepers' knowledge.

Case study location: Southwest region of WA

As identified, in WA beekeeping occurs primarily in the southwest portion of the state and forms the geographic boundary for this case study. The region lies southwest of a line from Shark Bay to Israelite Bay (east of Esperance) with the ocean providing a boundary to the South and West. The region has a Mediterranean climate with winter rainfall and hot dry summers although some summer rain is experienced along the south coast and into the interior. Annual rainfall generally ranges from >700mm to ~200mm moving west to east from the coast inland.

In 1969, the Governments Senior Apiculturist F.G. Smith produced a report titled 'Honey Plants in Western Australia' (Smith, 1969) in consultation with the Beekeepers' Section, Farmers' Union of WA as a guide to the geographic boundary and types of honey producing plants used by the state's beekeepers. Smith identified that beekeepers mostly operated in the South West Province with occasional use of resource in the Eremean Province. In 2004, the South West Province (302,627km2) was formally identified by scientists as the South West Australian Floristic Region (SWAFR) and declared a global biodiversity hotspot due to the extent of threatening processes which were impacting its highly biodiverse native flora and fauna communities (Hopper & Gioia, 2004; Myers et al., 2000). With subsequent analysis of herbarium records, an updated version of the SWAFR was produced (Gioia & Hopper, 2017) which further refined our understanding of the broad landscape ecology that is relevant to the region.

During Smith's time as an apiculturist, beekeepers would visit the drier interior of the southwest (Eremean Province) only when there were poor honey flows in the South West Province, as little was known of the honey potential of the Mallee (Smith, 1969). Since then, beekeepers have come to regularly use the Mallee. In recent decades this region was identified by scientists as 'The Great Western Woodland' (GWW) (Watson et al., 2008) and identified as one of the Earth's most ecologically significant regions. It lies east of the Rabbit-Proof Fence and is considered "one of the world's last wild places" (ibid, vi). It contains the largest and healthiest intact temperate woodland covering 160,000 square kilometres from the southern edge of the Wheatbelt to the pastoral lands of the Mulga country to its north, to the treeless Nullabor Plain to the east. Together the GWW and SWAFR comprise a resource base that is very important to the state's beekeepers (Table 1 and 2).

Contemporary beekeeper resource classification

For the purposes of this case study, the beekeeping resources across the SWAFR and GWW regions were reclassified to three broad ecotypes: Forests, Woodlands and Coastal resources. This simplified classification allows focus to be placed on

1) contemporary commercial migratory beekeeping and resource use patterns
2) the impact of varying resource governance and management regimes, and
3) the variety of competing interests

Table 1 maps this simplified classification to those developed by Smith (1969) and Gioia et al (2017). Table 2 identifies target flora in Forests, Woodlands and Coastal (West and South) resource types based on flora data provided by Smith (1969). Figure 3 illustrates the general boundaries of Forests, Woodlands and Coastal resources as described in Table 1 and in detail in Table 2.

Agricultural forage resources such as canola, pastures and weeds, which also provide important sources of nectar and pollen for beekeepers, are not included in this analysis as they are neither native flora nor managed by the state.

Table 1: Contemporary classification of beekeeping resources in southwest WA

Contemporary (2020) vegetation classifications used in Case Study			"Honey plants in WA" by Smith (1969)			New phytogeographic map for Southwest Australian Floristic Region from Gioia & Hopper (2017)	
Resource Type	Specific Resource	Floristic Regions	Region	Vegetation Zone	Vegetation Types	Province	District
Forests	Karri	South-West Australian Floristic Region	South-West Province	1	Karri / Marri Forest	Bibbulman	Muir
	Jarrah			2	Jarrah / Marri Forest	Bibbulman	Jarrah
	Marri			*3**		Bibbulman	Jarrah, Muir
Coastal	West			4	Heathland and Banksia Wooded Heathland – **West Coast**	Bibbulmun	Lesueur
	South			5	Heathland and Banksia Wooded Heathland – **South Coast**	Southeast Coastal	Esperance, Fitzgerald-Stirling Maalak
Woodlands				6	Wandoo Woodland Zone	Bibbulman Transitional Rainfall	Narrogin Wongan
				7	York Gum Woodland	Transitional Rainfall Kalbarri	Merredin Hyden Nanda Shark Bay
		Great Western Woodland	Eremean Province	8	Mallee Zone	Southeast Coastal Transitional Rainfall Province	Boylya Hyden
				9	Mulga Zone	Transitional Rainfall Province	

***** *Zone 3 - Tuart forests (Red tingle E. jacksonii and Yellow tingle E. guilfoylei) and woodlands are historically important resources for the beekeeping community (WA Farmers Federation Beekeepers Section, 2017). However, in 2019 they were listed as a Critically Endangered Community (Department of Climate Change, Energy, the Environment and Water, 2022) and have been excluded from analysis in this case study. Marri is classified as a separate resource type even though it grows in mixed forests with Karri and Jarrah.*

Table 2: Modified list of beekeeper resources combining historic (Smith, 1969) and more contemporary (Allan & Manning, 1992) classifications of melliferous flora.

Family	Genus		Common name	Forests	Coastal - West	Coastal - South	Wood-lands
Myrtaceae	Eucalyptus	diversicolor	Karri	X			
	Eucalyptus	marginata	Jarrah	X			
	Corymbia	calophylla	Marri	X			
	Eucalyptus	patens	Forest Blackbutt	X			
	Eucalyptus	redunca var. elata	Whitegum				x
	Eucalyptus	wandoo	Wandoo				x
	Eucalyptus	accedens	Powder bark wandoo				X
	Eucalyptus	rudis	Flooded Gum				X
	Eucalyptus	astringens	Brown Mallets				X
	Eucalyptus	gardneri	Blue Mallets				X
	Eucalyptus	occidentalis	Swamp Yate				X
	Eucalyptus	loxophleba	York gum				X
	Eucalyptus	salmonophloia	Salmon gum				X
	Eucalyptus	Oleosa var longicornis	Red morrel				X
	Eucalyptus	gracilis	Snap and rattle				X
	Eucalyptus	salubris	Gimlet				X
	Calothamnus	quadrifidus	Red bell / One-sided bottlebrush	X	X		
Proteaceae	Banksia	sp.		X	X	X	
	Banksia	menziesii			X		X
	Banksia	ilicifolia			X		
	Banksia	speciosa				X	X
	Dryandra	sessilis	Parrot bush		X		
	Hakea	trifurcata	Kerosene bush		X		
	Hakea	sp.					X
	Lambertia	inermis	Chittick			x	
	Xylomelum		Woody Pear				
Melaleuca				x			X
Casuarina	Allocasuarina	fraseriana	Sheoak		x		
Epacridaceae	Leucopogan				x		
Papilionaceae	Daviesia				x		
Mimosaceae	Acacia			X	X	X	X

Forests

Forests are native vegetation dominated by tall eucalypts in the wetter, southwest corner of the SWAFR, receiving more than 600mm of winter rainfall (Allan & Manning, 1992). For beekeepers, the dominant forest trees; Karri (*Eucalyptus diversicolor*), Jarrah (*Eucalyptus marginata*) and Marri also known as Redgum (*Calothamnus callophylla*) produce unique mono-floral honey which attract a premium price. Forests are a key resource for the industry and are sites of high contestation as they are managed by the state for multiple uses including recreation, conservation, timber, and bushfire protection. Since forests on private land have largely been cleared for agriculture, the majority of forest resources accessed by beekeepers are located on public land. Tenure of forested lands guide the objectives used to manage the resource and include National Parks, State Forests and Conservation Reserves. The Southwest Regional Forest Agreement (RFA) (DBCA, 2019) and decade long Forest Management Plans (FMP) (Conservation Commission of Western Australia, 2013) are the legislated policies that identify the principles upon which Forests are managed, for what values, and in whose interests.

Woodlands

Eucalypt woodlands are ecosystems resembling forests but with trees that are more widely spaced. This results in a more open canopy with crowns that do not often touch (Yates & Hobbs, 1997). They form a transitional zone between the higher rainfall forested margins of the continent and the shrub and grasslands of the arid interior. They occur within a mean annual rainfall range of 200-800mm. Floral diversity can be very high, with total number of species similar to that of Coastal Heath communities (Kwongan) (Yates & Hobbs, 1997).

Temperate woodlands have been extensively cleared across Australia. In WA, the wandoo woodlands, a key resource for early beekeepers, were extensively cleared for agriculture across the Wheatbelt. The Great Western Woodlands is the most significant area of temperate woodlands left in Australia (Watson et al., 2008) however, smaller pockets of woodlands still exist on public lands on the margins of the forests within the FMP boundaries. Much of the remaining woodland occurs within Conservation Reserves, National Parks or on Unallocated Crown Land (UCL). Key competing interests come from mining, bushfire management and the social influence/physical impacts of adjoining agricultural land.

Coastal

The Coastal category includes coastal heath, shrublands (also referred to as Kwongan) and banksia woodlands. These highly biodiverse flowering communities are located within tens of kilometres of the coast. The maritime influence moderates winter temperatures meaning bee populations can continue to forage in winter months. This reduces the incidence of colony loss more common in colder climates. Key floral species have sequential/overlapping nectar flows and spring is 'wildflower season' when a diverse floral community produces nutritious pollen which helps build thriving bee populations ready for the honey producing seasons ahead. 'In winter and spring, most commercial beekeepers operate on the coastal heath land of the northern coastal areas' (Allan & Manning, 1992, p. 8). There are two key areas for WA beekeepers; the West coast along the Swan Coastal Plain north

of Perth to Geraldton and the South coast between Albany and Esperance (utilised by beekeepers who base themselves nearby).

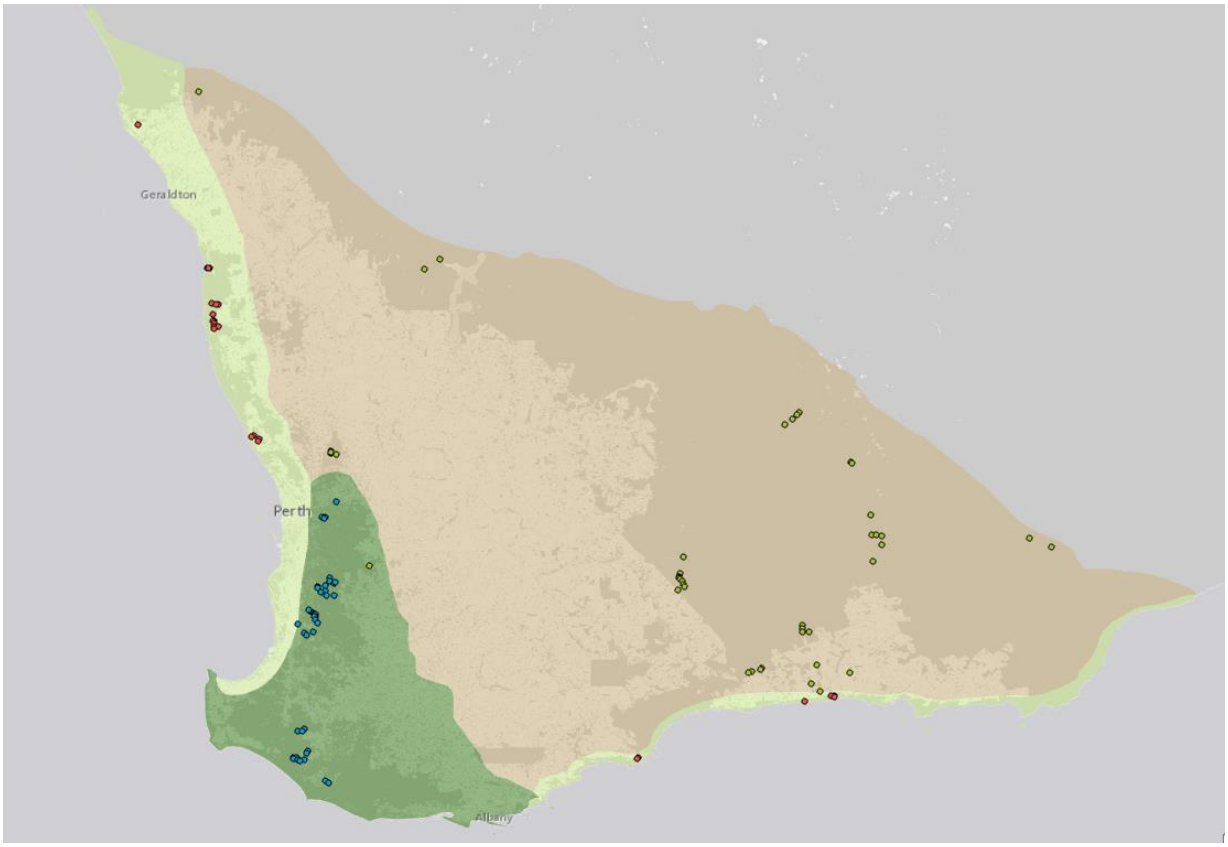


Figure 3: Beekeeper Resource Types. Green highlights the forests, pale green the coastal bush and brown the woodlands. Darker shades signify remnant vegetation. Lighter shades represent land that has been cleared.

Data Collection

This project sought to access diverse knowledge systems through both primary data collection (interviews and focus groups), and secondary data collection approaches (documents, archival materials, satellite information, databases). A key innovation of this research is '*B-harmony*' a stakeholder engagement toolkit designed to encourage the sharing of knowledges. This emerged from the process of engaging beekeepers, natural resource managers, scientists and academics in the field and seeking to understand the causal processes, which were contributing to beekeeper resource insecurity.

This section describes the two main sources of data used in this research, *participants* and *places*, as well as their interconnections. *Place* selection was driven by *participants*, and focussed on locations of importance selected by beekeepers, as well as biodiversity monitoring sites identified by resource managers.

Participant selection for Interviews and Focus Groups

The primary data for this research project was drawn from interviews and focus groups with participants from the commercial beekeeping industry and experts from government, industry and

academia (Table 3). A distinction was made between two types of commercial beekeepers based on level of experience. Type A were full time commercial beekeepers with greater than 10 years' experience operating successful businesses. Type B were commercial beekeepers, relatively new to the industry (less than 5 years' experience) and operating businesses in both a part-time and full-time capacity.

Interviews:

Semi-structured interviews were conducted with Type A and B beekeepers at their home or place of business. Semi-structured interviews were conducted with government officials and industry experts to understand their perspectives on the industry's resource security challenges.

Fieldwork:

- Interviews in-situ/ex-situ: Both Type A and B beekeepers were involved in one-on-one interviews in the field and through 'Desktop' Interviews (where photos from beekeeper's personal archives were used to illustrate understandings of the natural environment in which they operate).
- Focus Groups in-situ: Focus groups of varying sizes (from 2 to 4 participants) were conducted with a research team (of 3 to 4 people) in the field. Participants included Type A beekeepers, government officials (scientists and practitioners from the resource manager) and academics. Academics were environmental system experts unaffiliated with either the industry or resource manager.

The number of participants involved with each data collection approach are provided in Table 3.

Table 3: Research participants by data collection approach

Participants	*Ref.*	*Description*	*Sample population size*	*Interviews*	*Fieldwork – in Situ*		
					Interviews	*Focus Groups*	*Both*
Commercial Beekeepers	A	Type A: Experience level >10 years	14	12	1	4	2
	B	Type B: Experience level <5 years	5	5	3	0	0
Resource Manager	G	Practitioners and Scientists from DBCA	6	1	0	5	0
Outside Industry or Govt	E	Academics, Industry Experts	4	2	0	2	0
		Total	29	20	4	11	2

Research Site Selection

Research sites were selected in collaboration with participants in order to gather insight into beekeeper resource security concerns. Participants selected locations in consultation with the

research team (Table 4). Fieldwork was conducted at 97 sites using multiple methods of data collection (Figure 4 and Figure 9). Twenty long-term biodiversity monitoring sites were visited in Forests and Coastal regions (Figure 9) and targeted for focus group discussions between beekeepers and the scientists responsible for establishing them.

Site types: Biodiversity Monitoring Sites and Beekeeper-selected sites

Attention to 'place' was an important aspect of the methods used to elicit expert knowledges and fill knowledge gaps. Two types of meeting place were used in this project to facilitate conversation, biodiversity monitoring sites (BDMS) and beekeeper-selected sites (AS). Figure 5 shows the proportion of sites by resource category. Beekeeper-selected sites were an opportunity for industry participants to take the research team to locations which offered tangible evidence of the impact of competing interests. Biodiversity monitoring sites allowed participants to compare different resource management regimes including fire and silviculture (logging).

Table 4: Method, site and participant selection criteria

Method	*Site selection*	*Participant selection: commercial beekeepers*	*Participant selection: non-beekeepers*
Interviews in situ	Beekeeper-selected sites	Type A or B, single beekeeper only	None
'Desktop' interview	Beekeeper-selected sites	Type A	None
Focus Group in situ	Beekeeper-selected sites	Type A, single or multiple beekeepers	Government officials, academics or industry experts
Focus Group in situ	Biodiversity monitoring sites	Type A, single or multiple beekeepers	Government officials and/or academics

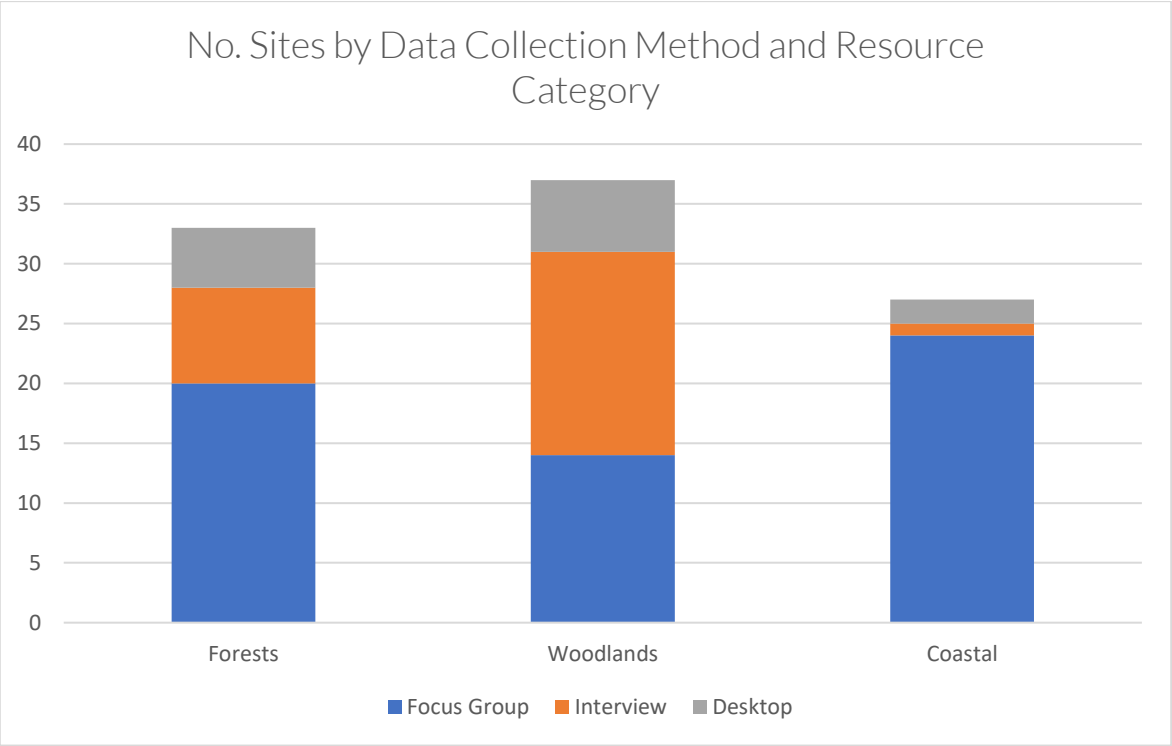


Figure 4: Proportion of Field Sites by Data Collection Method and Resource Category

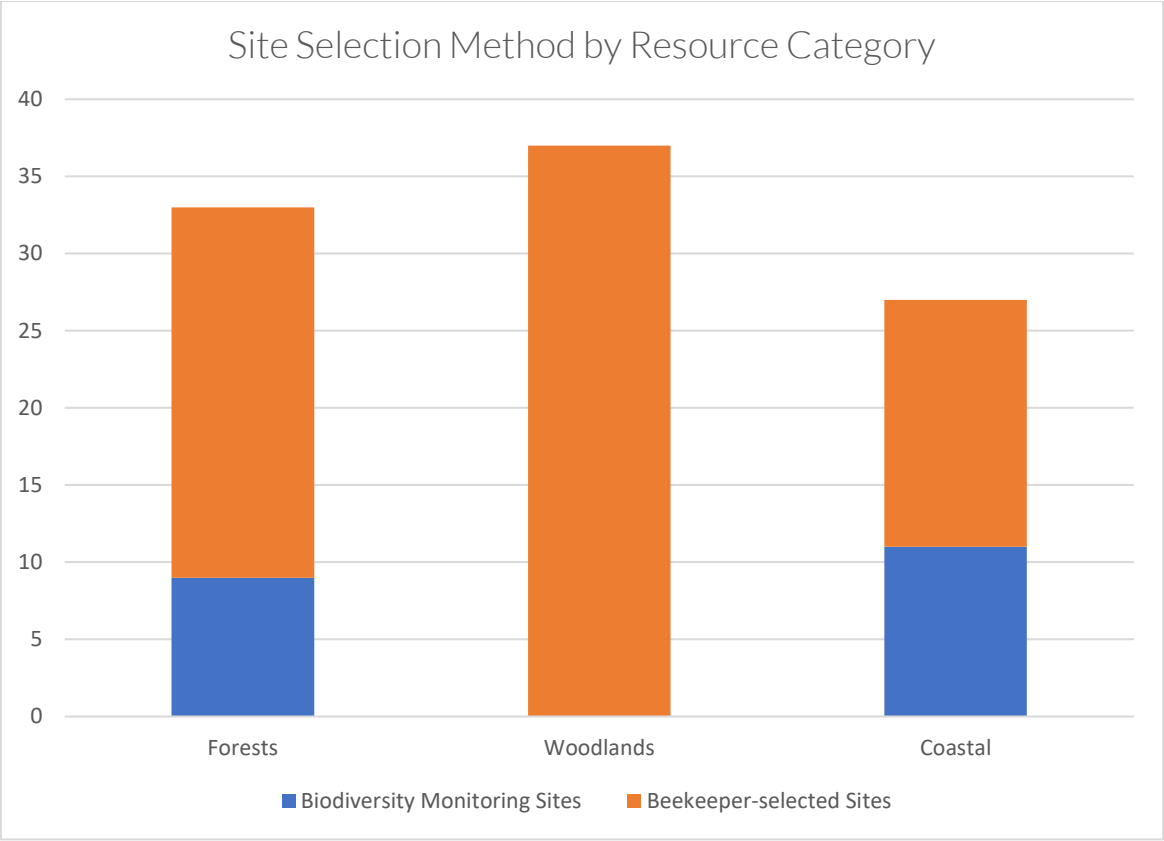


Figure 5: Site Selection Method by Resource Category

At each location, discussions focused on the values beekeepers ascribed to the environmental features of the site ('apiary site values'), their local ecological knowledges, relevant livelihood practices that contributed to their knowledge base, and relationships between beekeepers and other resource users and managers ('competing interests'). 'Apiary site values' refer to aspects of the environment that beekeepers monitor and assess to predict the future productivity of a location. 'Competing interests' refer to other users and uses who ascribe values to a resource, and if prioritised, would prevent beekeepers from realising apiary site values. Note, apiary site values do not refer to nectar and pollen in and of themselves. These values are the qualities of the environment that promote bee health and high productivity.

The focus groups at BDMS included scientists involved in the establishment of the site and Type A beekeepers recognised as expert users of the resource. A key focus of the discussion was centred on how apiary site values reflected the known disturbance history of the site (Figure 6).

Table 5 identifies the type of sites visited to facilitate focus group discussions (beekeeper-selected sites including apiary sites 'AS', or biodiversity monitoring sites 'BDMS').

Table 5: Field sites visit for focus group discussion

Trip	Participants (# Type)	# Research team members	# Sites	Site Code	Date of Field Trip	Time in Field	Area	Resource Type	Site Type
1	1B	1	3	PV_1-3_JL	27/07/2020	3 hrs	Julimar State Forest	Woodland - Whitegum	AS
2	1A	1	13	PV_4-12 PV_86-87 PV_ 95-96	12/08/2020	3 hrs	Chidlow	Forest - Jarrah Woodland - Whitegum, Mallee Coastal Heath - West	AS
3	2A, 1E	3	5	PV_13-17_SB	24/08/2020	2 hrs	Lancelin	Coastal Heath - West	AS
4	1A, 1E	3	14	PV_18-31_BK	25/08/2020	1 day	Beekeepers Reserve	Coastal Heath - West	BDMS
5	1B	2	8	PV_32-39_PB	14/09/2020	1 day	Pemberton	Forest - Karri	AS
6	2A, 1G	4	12	PV_40-51_DW	2/12/2020	1 day	Dwellingup	Forest - Jarrah	BDMS
7	1A	4	9	PV_52-60_FO	11/01/2021	0.5 day	Forestania	Woodland - Mallee, Mallet	AS
	1A, 1G, 1E	4	6	PV_61-66_NO	12/01/2021	0.5 day	Norseman	Woodland - Mallee, Mallet	AS
	2A, 1G, 1E	4	6	PV_67-72_CC	12/01/2021	0.5 day	Cascade	Woodland - Mallee, Mallet	AS
	1A, 1G	3	2	PV_73-74_YR	13/01/2021	0.25 day	Young River	Woodland - Mallee, Mallet	AS
	1A, 1G	3	5	PV_75-79_SI	13/01/2021	0.5 day	Stokes Inlet	Coastal Heath - South	AS
	1A	3	4	PV_80-83_RV	13/01/2021	0.15 day	Ravensthorpe	Woodland - Mallee, Mallet	AS
	2A	3	1	PV_84_RV	13/01/2021	0.1 day	Ravensthorpe	Woodland - Mallee, Mallet	AS
	1B	4	1	PV_85_BY	14/01/2021	2 hours	Bremer Bay	Coastal Heath - South	AS
8	1A, 3G	3	8	PV_88-94_97_HV	15/03/2021	1 day	Harvey	Forest - Jarrah, Marri	AS
Participant types		A = Type A Beekeeper		G = Government Official			**Site Types**	AS = Apiary Sites	
		B = Type B Beekeeper		E = Academic Expert				BDMS = Biodiversity Monitoring Sites	

The following provides a brief background on the biodiversity monitoring schemes that provided locations where focus group discussions were conducted.

Biodiversity Monitoring Sites in Forest: Jarrah

Biodiversity Monitoring Sites in Forests, predominantly Jarrah, were selected from two monitoring schemes, 'FORESTCHECK' focused on biodiversity monitoring, and the 'Inglehope Thinning Trial' which monitors the impact of thinning on the growth trajectories of select jarrah stands.

FORESTCHECK is an integrated monitoring system designed to support forest management in the southwest of WA. It was established by the state environment agency circa. 2000 in response to community concerns over timber harvesting, with a focus on identifying impacts on key elements of forest biodiversity associated with management activities. Monitoring is a key component of adaptive management and is fundamental to Ecologically Sustainable Forest Management (Robinson, 2012). Whilst the focus of FORESTCHECK was initially on timber harvesting and silvicultural treatments in jarrah as an outcome of the *Regional Forest Agreement* process (McCaw et al., 2011), additional monitoring sites were added to assess the impact of fire regimes on biodiversity. Analysis of FORESTCHECK data published in 2011 (Farr et al., 2011; McCaw, 2011; McCaw et al., 2011), concluded that few significant impacts of silvicultural regimes were evident. Whilst species richness was not impacted by different silvicultural treatments, species composition did differ across monitoring sites. Monitoring also showed that soil compaction from harvesting required more than 50 years to reverse, and time since prescribed burns had not had a long-term impact on any species group. It was noted that very few taxa were sufficiently widespread or responsive to disturbance to be of value as bioindicators. This was considered to indicate the superiority of biodiversity monitoring over bioindicator monitoring (Robinson, 2012).

Figure 6: Forest: Jarrah - Focus group at FORESTCHECK biodiversity monitoring site

Figure 7: Forest: Jarrah – Focus group at Inglehope Thinning trial monitoring sites

The 'Inglehope thinning trial' was established to measure the gains in timber production from thinning and fertiliser application on jarrah forest (Bhandari et al., 2020). It does not however, specifically consider the biodiversity impacts of thinning. Figure 7 shows the focus group at one of the trial sites.

Figure 8: Focus group participants at Northern Beekeepers Reserve biodiversity monitoring sites

Biodiversity Monitoring Sites in Coastal: West

Northern Beekeepers Reserve is a dedicated nature reserve for beekeeping located near Greenhead and Jurien Bay, approximately 250km north of Perth. In 1985, 90 flora and fauna monitoring plots were established and measured as part of PhD research designed to inform resource management of flora utilised by honeybees in the Coastal resources of the northern sandplain (Kwongan) (Wills, 1989). A key finding of this study was that 'while short term loss of (honey) production results from the immediate effects of fire, the problem of modification of plant communities by short interval fires reducing or eliminating key honey-producing species is much more serious' (Wills, 1989, p. 236) Eleven of the 90 sites were used by this research (Figure 8).

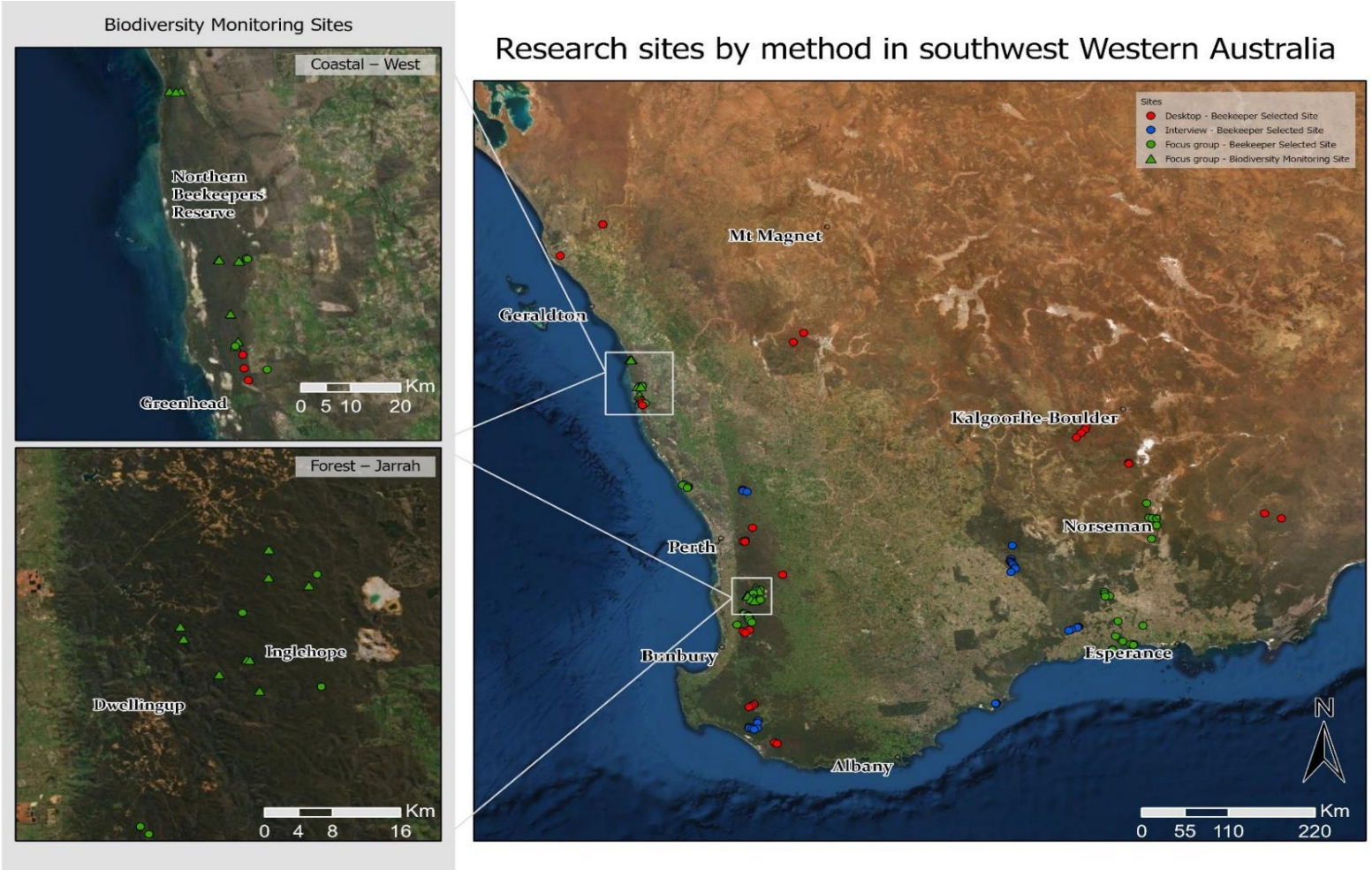


Figure 9: Map showing research site locations by method of site selection and data collection

Research Innovation: "*B-Harmony*" in-situ focus group facilitation approach

A key dynamic between the industry and resource managers stemmed from a sense of frustration over the inability to effectively communicate about resource security issues. This may have resulted from the historically transactional relationship between beekeepers and land managers which was centred on the apiary site permitting processes rather than the environment itself.

To redirect the conversation, a method was developed using 'place' (location) to contextualise conversations about environmental change. '*B-Harmony*' emerged from conducting focus groups in the field with a mix of experienced beekeepers, government officials, scientists and academics (Figure 10). The method provides an effective approach for developing a common language and shared understanding of the environment whilst drawing from diverse perspectives.

To this end, co-production of knowledge was facilitated by empowering research participants to select locations within the environment as catalysts for conversation. The research team recorded dialogue occurring at each location and captured photographs of key environmental features being discussed. By using both beekeeper-selected sites and established monitoring sites, the power dynamic was shifted highlighting values of, and features of the environment important to participants. This encouraged information exchange grounded in notions of stewardship and shared values.

B-Harmony

Purpose: To explore drivers of change in apiary site values and how they contribute to beekeeper resource insecurity.

Method: Facilitated focus group discussions in the field between expert stakeholders using sites selected by participants as a stimulus for discussion on drivers of environmental change.

Participants: Beekeepers as local expert ecological knowledge holders. Government officials and academics as experts in natural resource management.

Sites: Sites chosen by participants in consultation with the researcher. Sites were selected as examples of environmental changes that was affecting beekeeper resource security. The locations provided the context for facilitated discussions about apiary site values and drivers of change. Sites were selected to gain appropriate coverage of the three resource types, relevant target flora and resource security issues. 59 sites were visited for focus group discussions; 39 were apiary sites and 20 were biodiversity monitoring sites (Figure 5).

Figure 10: B-Harmony with focus groups in the field

Data collection in the field

A variety of methods were used to capture data when in the field. The primary purpose was to capture sufficient detail to facilitate analysis across a range of locations.

Audio Recordings: All conversations in the field were audio-recorded and later transcribed.

Photography: One or more of the research team took photographs during the site visits to record the key attributes of the location and specific aspects of the environment being discussed by participants.

Field Notes: Field notes were recorded at each site including time, date, location, participants, target species, drivers of change and other points of discussion.

Geographic Positioning System (GPS): Each site location was recorded to facilitate incorporation of sites and additional geospatial data using a Geographic Information System (GIS).

Figure 11 provides a selection of images to demonstrate how data was captured in the field.

Figure 11: Capturing data in the field; audio recorders, photography, GPS, field notes

Data preparation

Data was prepared for analysis by transcribing audio recordings which were then collated into individual site records as per Figure 12 (example excludes transcripts).

Photovoice Site Ref:	PV_76_SI
Date:	13 January 2021
Time:	13:10 PM
Locale:	Stokes Inlet - coastal
Tenure:	
Site Location:	_024
Site Coordinates (degrees):	
Site Coordinates (decimal):	-33.813833° 121.296350°
Apiary/Monitoring #:	4742
Participants:	B17, G2
Researchers:	LW CM VP
Audio file/s:	210113_1310
Transcriber:	LW
Photos:	(CM 101) DCM_83-91 (VP) IMG_4918-4925
Photographer:	CM VP
DBCA Apiary Portal Map:	BKApp_3_PV_75_SI
Google Earth Image:	GEI_65_PV_76_SI
Treatment history	

GE Image: GEI_65_PV_76_SI- burnt nth sth strip 2004

DBCA Apiary Portal Map: BKApp_3_PV_75_SI

Document: 20150342_esperance_recherche_management_plan_web.pdf

Photo: DCM_0083, 85, 90, 91 (driving, roads)

Photo: DCM_0084 (GPS)

Photo: IMG_4918, 22-25 (landscape)

Photo: IMG_4919, 21 (chitock)

Photo: IMG_4920 (banksia)

Audiofile 210113_1310

00:02

Figure 12: Example Site Record (transcripts excluded)

Secondary Sources

Secondary sources of data from archival materials, literature, databases and satellite imagery (**Error! Reference source not found.**) were used to account for additional perspectives and to triangulate the knowledges shared by participants about environmental change and drivers of beekeeper resource insecurity.

Table 6: ***Secondary sources of data***

Data Type	*Sources*	*Links*
Archival Materials including photos	State Library National Library Personal archives of research participants	www.slwa.wa.gov.au www.nla.gov.au
Participant records	Business data	
Published Academic Literature	Peer reviewed research	
Non Academic 'Grey' Literature	Published information from reputable sources (e.g. Government departments)	
Databases	DBCA Fire database Apiary Site location database BOM climatic records	(Hamilton et al., 2009) www.dpaw.maps.arcgis.com/apps www.bom.gov.au
Satellite images	Google Earth Pro Planet	www.google.com/earth www.planet.com
Legislation	WA State Legislation	www.legislation.wa.gov.au

Data Analysis

A challenge of working with diverse sources of qualitative information is synthesis and analysis. Here, interviews and field records were thematically coded and mind maps developed to show system connections identified by participants. These connections were verified by sourcing and synthesising data from literature, databases and historical records.

Systems Analysis: Commercial beekeepers conduct their livelihoods within complex, adaptive social-ecological systems. The Australian beekeeping industry operates at the nexus of many traditionally siloed areas of society, environment, governance and resource management including environmental management and agriculture. In a parallel project within the CRC, Patel et al (2020) used Ostrom's Social-Ecological Systems Framework (Ostrom, 2009) to conceptualise the WA Beekeeping industry and relationships with resources and natural resource governance. However, this model did not demonstrate how competing interests in apiary site resources were influencing resource insecurity. Using a reflexive thematic method of analysis, this project developed the *Australian Commercial Beekeeper Framework (ACBKF)* based on the IPBES[1] Conceptual Framework (CF) (Diaz, Demissew, Carabias, et al., 2015). The IPBES CF was developed by international biodiversity experts as a framework to facilitate knowledge exchange between diverse stakeholders around institutional governance of biodiversity and ecosystem services (Diaz, Demissew, Joly, et al., 2015).

[1] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

Results

The results of this analysis are presented as answers to four research questions framed through the perspectives of Systems Thinking, Sustainable Livelihoods, History, and Environmental Change. First, '**Systems Thinking**' was used to understand the ways in which beekeepers interact within and between human and environmental systems. A systems view allows for an enhanced understanding of interconnectivities between livelihoods, forage availability and access, competing interests and the natural resource management approaches that govern the system. A '**Livelihoods'** perspective provides for an appreciation of how beekeepers interact with their environment through livelihood practises, highlighting the importance of forage resources and environmental health. A '**Historical'** perspective allows for a temporal analysis of how resource insecurity has evolved over time, often resulting from power dynamics between beekeepers, resource managers and competing interests. Finally, an '**Environmental Change**' perspective provides an understanding of how natural processes magnify anthropogenic impacts on the quality and quantity of the floral resource beekeepers depend on.

The results presented in this report are a brief version of the full and detailed analysis provided in the PhD thesis.

Q1: Systems Thinking

The results of this analysis answered the question:

What social-ecological system allows commercial migratory beekeepers to benefit from native floral resources on public lands?

In this report only a simplified visual representation of the Australian Commercial Beekeeper Framework is provided (Figure 13). A brief description of how the various elements interact is first provided and then Table 7 describes each element in more detail. A full description of the framework and its application to the case study area is provided in the thesis.

Description of the system: Australian Commercial Beekeeper Framework (ACBKF)

Keeping honeybees as a commercial beekeeper relies on access to healthy, biodiverse landscapes for resource security. Beekeepers make substantial contributions to human health, wellbeing and food security. They rely on healthy, biodiverse natural ecosystems to provide the nectar and pollen bees produce honey products from. These resources are also required to deliver pollination services. Commercial beekeepers need a diverse set of skills and effective networks to maintain a sustainable livelihood. A unique aspect of their livelihood is that they do not control the environmental resources that they rely on. Resource quality is often a function of how it is managed however, beekeepers do not generally control the resources they use, and access is governed by public and private landholders. Within WA, quality productive forage has been influences by climate change, fire regimes and competing resource use.

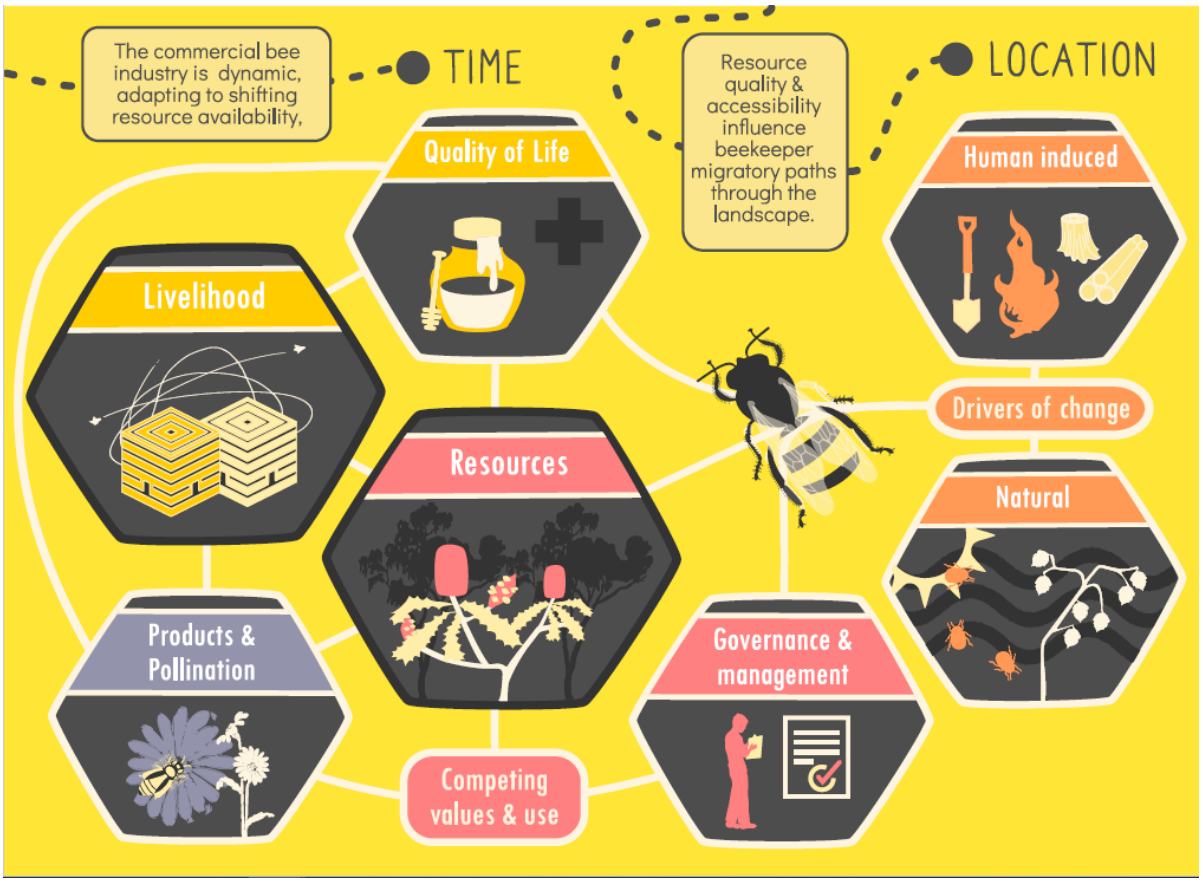


Figure 13: Infographic - Commercial Beekeeping in Australia (a representation of the Australian Commercial Beekeeping Framework

Table 7: Description of the components of the Australian Commercial Beekeeping Framework

Key Element from IPBES CF	*Key Element from ACBKF*	*Application to Australian Commercial Beekeeping*	*Brief description of the element with reference to beekeeping and its dependence on resources*
Good Quality of Life	Good Quality of Life	Beekeeping Lifestyle	Often multi-generational family business practice. Connection to the land. Contribution to society.
		Food Security	Pollination of agricultural and horticultural crops ensures crop set and increases productivity
		Human Health & Wellbeing	Honeybee products from clean, green, authentic sources with medicinal and therapeutic properties
Anthropogenic Assets	Livelihood	Business skills	Including decision making, logistics, marketing, sales, distribution
		Capital	hives, infrastructure, plant and machinery, social, cultural
		Knowledge	Including beekeeping and local ecological knowledges
		Networks	gain knowledge and resources
		Resources	apiary site portfolio, genetics, stock
Nature's Contribution to People	Products & Pollination	Honeybee products	Nectar and Pollen converted to products (like honey, royal jelly, propolis, wax) by managed honeybees
		Pollination	By managed honeybees, native pollinators and feral honeybees
Nature	Resources	Resource Types	Coastal, Forests, Woodlands, (Agricultural)
		Apiary Site Values	Ecosystem maturity, Biodiversity, Ecosystem health, Water availability, Accessibility
Institutions and Governance	Governance, Management	Natural Resource Management	Apiary site permits and access conditions Natural Resource Governance and Management of resources; Indigenous management
		Industry regulator	Biosecurity, Registration of beekeepers
		Beekeeping Industry	Association, State, National Representation
Other indirect drivers	Competing Values & Uses	Economic Context	Market for honeybee products and pollination services, Apiary site availability
		Social Context	Beekeepers social licence to operate; 'Honeybees shouldn't be in conservation areas' narrative; 'Saving the Bees' narrative; Social licence of competing users and industries
		Competing Resource Users	Forestry, Mining, Agriculture, Land Developers, Tourism, Recreation, Fire Management (Property and Life priorities), Conservation other Non-Timber Forest Product users
Drivers of Change: Natural and Anthropogenic	Drivers of Change	Human Induced	climate change, imposed fire regime, clearing vegetation (incl. silviculture & rehabilitation), soil disturbance, chemicals, introduced pests, weeds, diseases
		'Natural'	Wildfire, drought, floods, pests, diseases, weeds, feral animals
Changing over Time	Time	Honeybees are an introduced species to the Australian landscape	Honeybee history in the Australian landscape begins shortly after colonisation (1846). The beekeeping system and the landscape have co-evolved since then to the present day. Multi-year rhythms of resource flowering; Seasonal rhythms which influence annual migrations
Interacting across spatial scales	Location	Local to Regional	Beekeepers migrate hives between individual apiary sites that make up a portfolio of sites which are societally constrained within the geographic region

Q2: Livelihoods

The results of this analysis answered the question:

What practices, values and knowledges are used by commercial beekeepers to secure resources to sustain livelihoods?

Developing expert knowledge required to navigate the floral landscape and acquiring a portfolio of apiary sites to secure access to sufficient resources is fundamental to becoming a successful commercial beekeeper (Figure 14). 'Apiary site values' has been developed through this research to describe a set of values which beekeepers monitor and assess at both the site and landscape scale to decide which locations will support healthy productive bee colonies. When assessing an apiary site's value, access to the site and the flowering stage of melliferous flora targeted for honey production (such as the eucalypts) are the initial focus and drives the decision-making process. However, there are other aspects of the environment that influence productivity (Figure 15). For instance, maturity of the target flora, the availability of moisture in the environment, the health of the vegetation and level of biodiversity at a site will all influence production over time. Monitoring the environment and its influence on productivity is a key means by which beekeepers cultivate local ecological knowledge (LEK). LEK is vital to sustaining honeybee colonies and producing commercial quantities of honeybee products. Beekeepers LEK is a direct reflection of their commercial interest in the reproductive health of native floral resources.

Whilst LEK is vital for commercial operators, site access is paramount. Accessing locations which offer foraging opportunities and where hives can be safely located is achieved through negotiations with landowners and/or resource managers. For public apiary sites, a standard set of terms and conditions govern the use of a site, but in broad terms, beekeeper's have little influence over how the floral resources are actually managed. Yet, beekeeper values are commensurate with contemporary resource management paradigms where the priority is to conserve biodiversity and limit the negative environmental impacts of human activities.

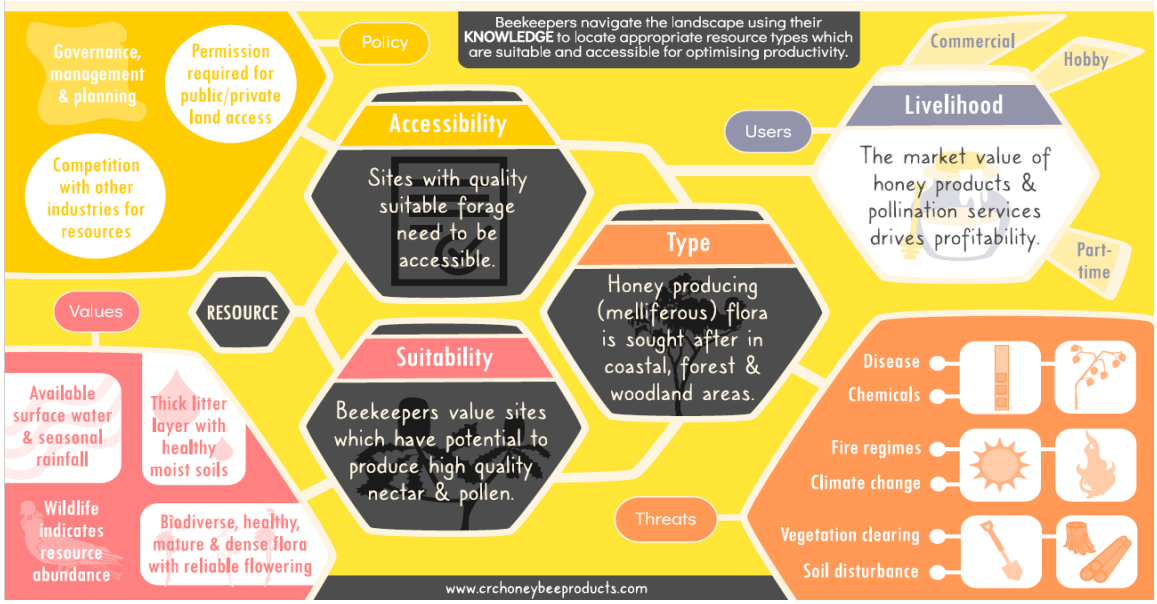


Figure 14: Infographic - Navigating resources as a beekeeper in Western Australia

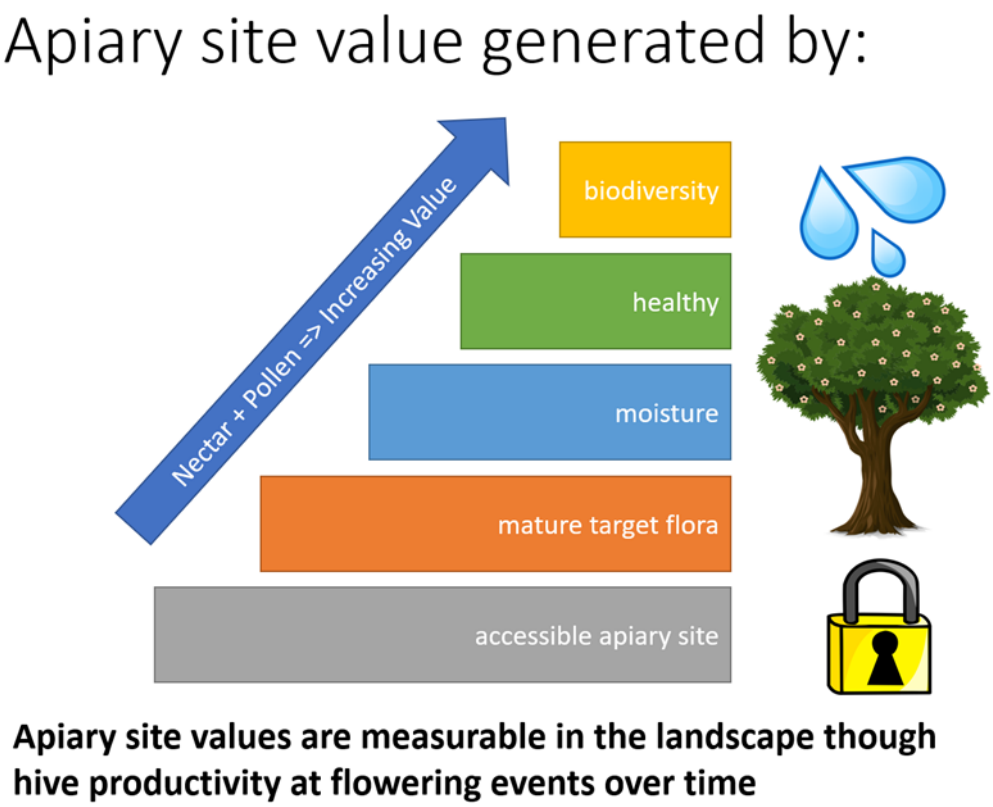


Figure 15: Apiary Site Values - attributes which contribute to increasing value of an apiary site

Q3: Historical

The results of this analysis answered the question:

How has the issue of beekeeper resource insecurity emerged over time? What processes and powers have supported and restricted access?

Given the heavy reliance on native flora, a key attribute of the WA commercial beekeeping industry is that livelihoods have co-evolved with changes in the environment. Changes to the resource base have been a consequence of natural resource governance (policy and planning), management (on-ground activities to meet policy objectives) and competing interests. The emergence of beekeeper resource insecurity is associated with a decline in the quality, quantity and level of access beekeepers have to floral resources.

Using a timeline approach, an overview of the WA beekeeping industry's 'dance with the resources' was penned (Figure 16 to Figure 19). The purpose of this analysis was to trace pathways that have led to the emergence of resource insecurity and highlight where path dependencies have influenced contemporary natural resource management policy and practice. Key drivers of the current pathway include development of the timber, mining and agricultural industries, changes in fire management practices and the conservation movement. These competing values and interests have influenced governance practices over time resulting in a suite of anthropogenic drivers of change. The effects of

these disturbances are often amplified by climate change, which then reduces ecosystem resilience and ability to recover from system shocks. This is often reflected in the reproductive health of the system beekeepers rely upon.

In summary, the research captures how the beekeeping industry brings a unique perspective on how we manage complex environmental landscapes in WA. These landscapes are typically monitored and managed in fragmented and competitive ways. The beekeeper's perspective has been marginalised in WA public land management and historical accounts of land development. However, this research shows that their experience has a lot to contribute to public debates on land management in WA. Taking a historical view of beekeeping livelihoods and the emergence of resource insecurity underwrites the novel findings of this research which include:

- That the beekeeping industry experience offers unique insight because it spans environmental landscapes that are typically fragmented by sector and managed in siloes.
- The role of dominant narratives and their consequent path dependencies on public resource management which reflect changing socio-cultural values over time.
- The power and consequences of prevailing resource management narratives on beekeeper's access to resources which results in resource insecurity.
- That the emergence of resource insecurity is also the consequence of the cumulative impacts of environmental disturbance regimes (explored in the next section of results).
- Putting the industry's experience into historical perspective showcases how their capacity for stewardship goes unrecognised in the prevailing regimes yet offers potential to significantly improve future resource management planning.

1830s – 1920s Local Beekeeping

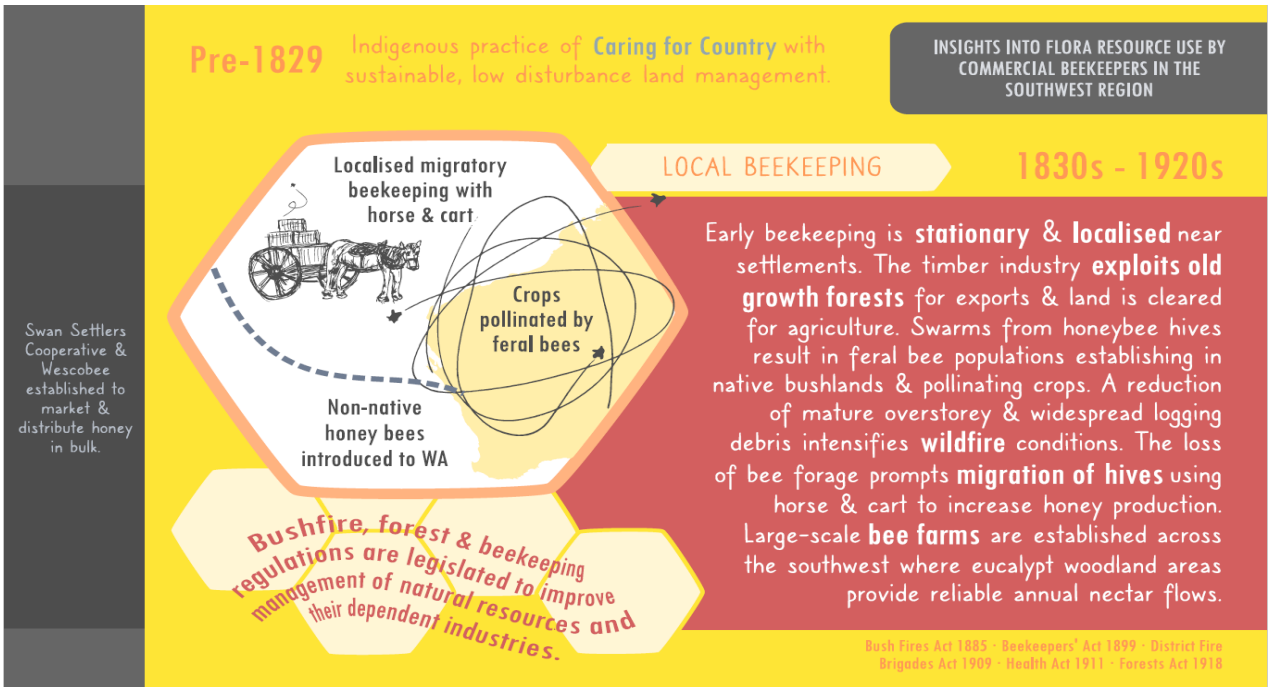


Figure 16: Infographic - Beekeeping in WA, 1830s-1920s

1930s – 1960s Commercial Beekeeping

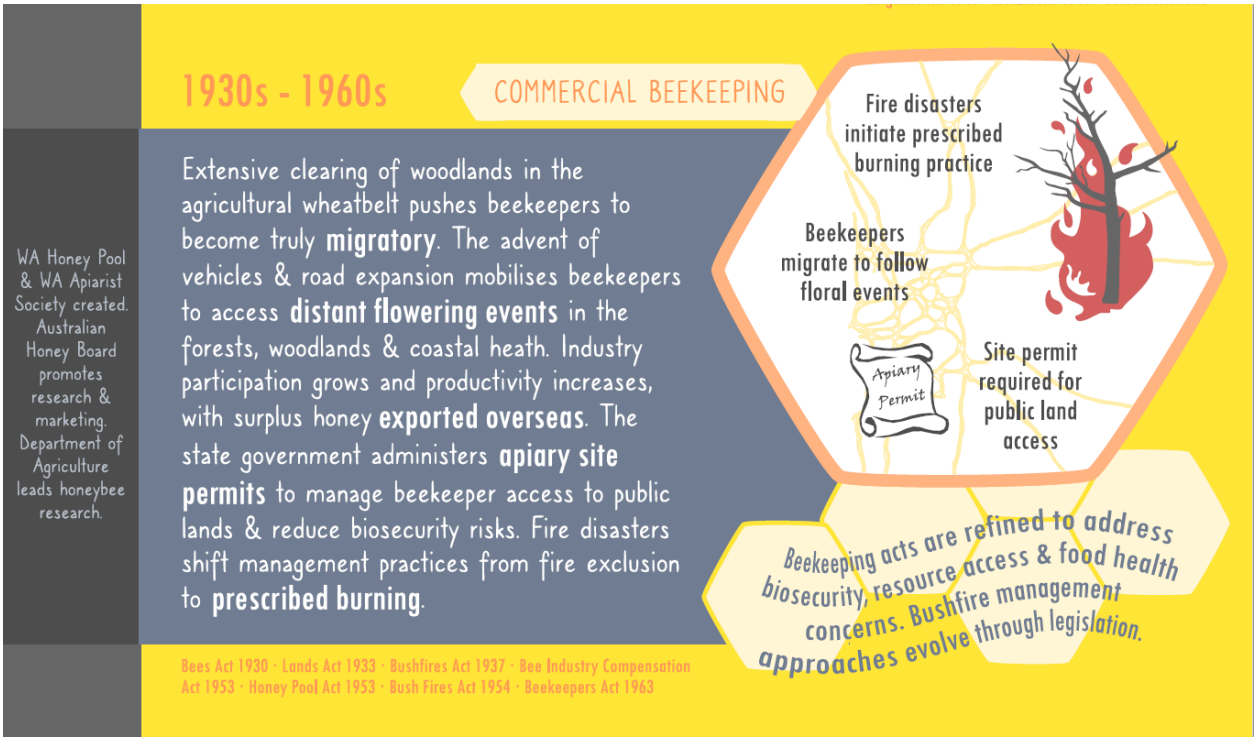


Figure 17: Infographic - Beekeeping in WA, 1930s-1960s

1970s - 2000s Industry under pressure

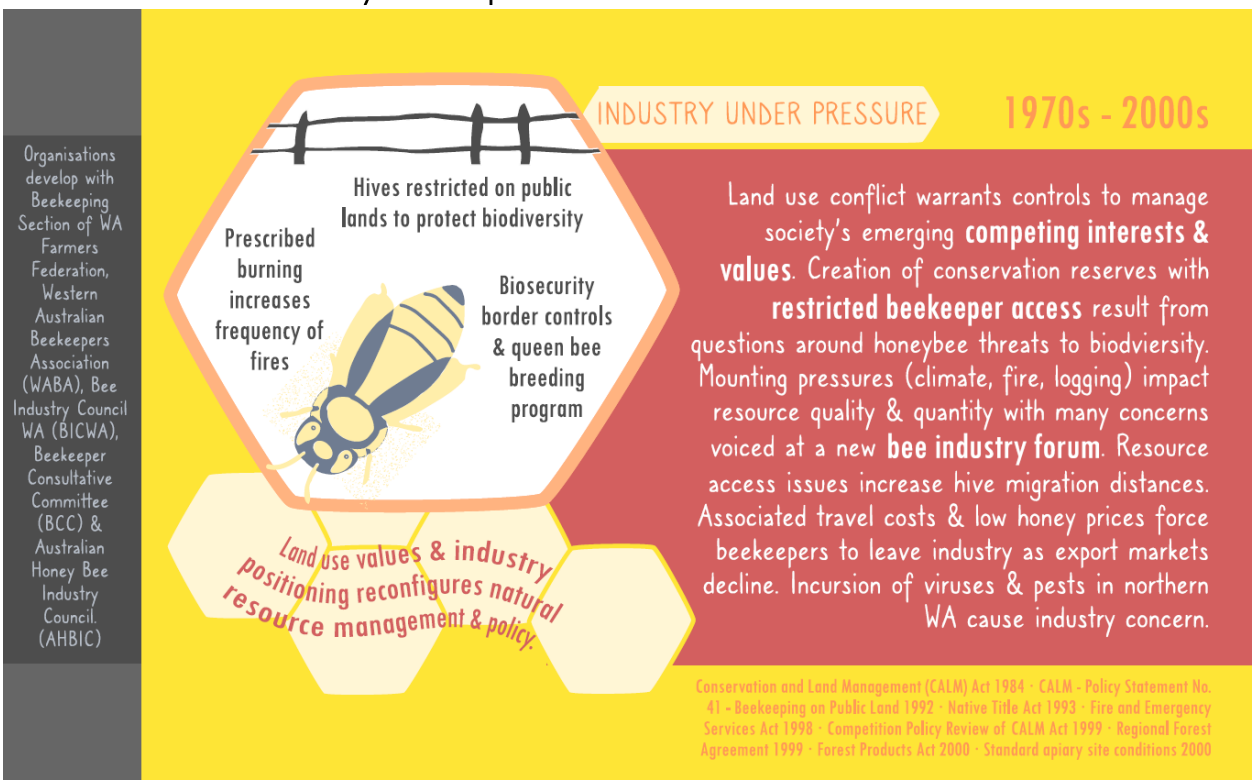


Figure 18: Infographic - Beekeeping in WA, 1970s-2000s

2010s - 2020s Industry Revival but Resource Insecurity threatens future prosperity

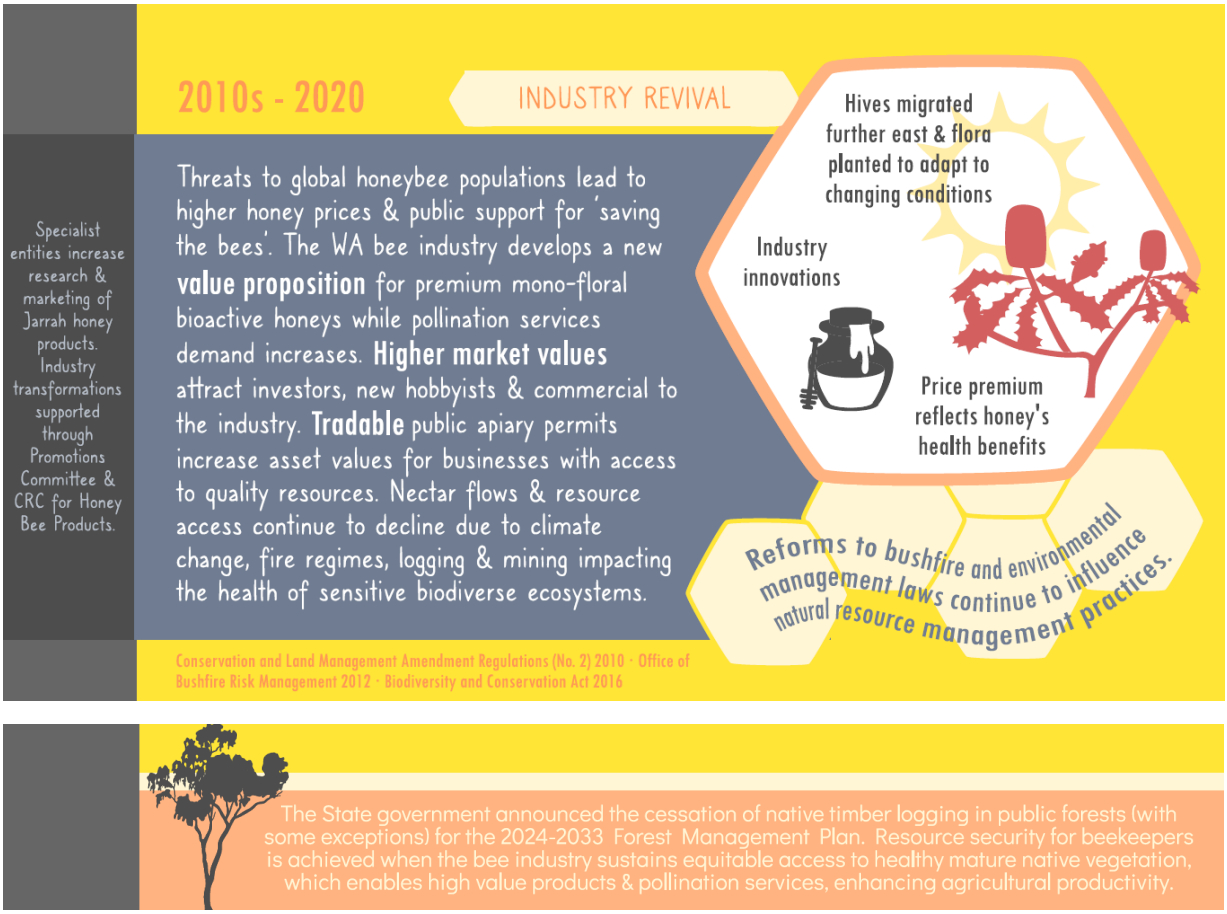


Figure 19: Infographic - Beekeeping in WA, 2010s-2020

Q4: Environmental Change

The results of this analysis answered the question:

What environmental changes affect the availability of apiary site forage resources? What are the drivers of change?

'Apiary site values' (i.e. access, mature flora, moisture availability, health and biodiversity) (see Figure 15) are sensitive to disturbance regimes imposed by competing resource uses. Figure 20 describes the physical manifestation of 'apiary site values' that have been impacted by adverse outcomes from disturbance regimes. Disturbances degrade the value of these resources reducing nectar and pollen production.

Disturbances regimes in the southwest of WA are broadly classified here as; vegetation clearing, climate change, fire, soil disturbance, (agri)chemicals, pests, weeds and disease.

Table 8 associates this broad classification with specific disturbance activities, the resource types affected by each and the impact on 'apiary site value'.

Table 9 identifies the competing uses and users whose activities are associated with each disturbance regime.

Whilst the temporal impact of a disturbance activity on 'apiary site values' may in some cases be relatively brief, those of significant concern to beekeepers are ones which have sustained negative impacts and last for years or decades. The persistence of these impacts is often a reflection of:

- the severity and frequency of disturbances,
- the ecological characteristics of the target flora (particularly its reproductive strategies), and
- the general resilience of the ecosystem which is often determined by its health prior to the disturbance event.

To this end, loss of 'apiary site value' is a key driver of resource insecurity but could be better protected if recognised as part of the natural resource management process. If the environment were to be managed in a way that guards the value of apiary sites, the environment would be more productive overall. It should be noted that climate change is having a greater influence on environmental health and productivity with apiarists requiring access to more sites in order to mitigate the impact of annual climate variability. Still, if beekeepers were able to contribute their ecological knowledge to improve natural resource management processes, better environmental health outcomes could be achieved.

Table 8: Disturbance regimes that affect apiary site values by resource type

Drivers of Change		Resource Types impacted			Which apiary site values are negatively impacted				
Disturbance Regime	Disturbance Type	*Coastal*	*Forests*	*Woodlands*	*Access*	*Maturity*	*Water*	*Health*	*Biodiversity*
Vegetation Clearing	Clearing and Land Use conversion - agriculture	x			x	x	x	x	x
Vegetation Clearing	Chaining followed by regeneration for firebreaks	x		x	x	x			
Vegetation Clearing	Clearfell logging followed by regeneration - Gap cut		x	x	x	x	x	x	x
Vegetation Clearing	Selective Logging retaining some mature elements - Thinning, Shelterwood		x		x	x		x	x
Climate Change	Unseasonal rainfall patterns	x	x	x			x	x	
Climate Change	Rising Temperatures	x	x				x	x	
Fire	Wildfire	x	x	x	x	x	x		x
Fire	Prescribed Burning	x	x	x	x	x	x	x	x
Soil Disturbance	Soil compaction		x					x	
Soil Disturbance	Soil movement	x	x	x				x	
Introduced Pests, Weeds, Diseases	Dieback	x	x	x				x	
Chemicals	Spray drift			x				x	

Table 9: Association between Competing Users and Disturbance Regimes

Competing Users	Disturbance Regime influenced by Competing Users			
Industry/Institution	Vegetation Clearing	Fire Regime	Soil Disturbance	Chemical
Industry				
Forestry	X	X	X	
Mining	X	X	X	
Agriculture	X	X		X
Land Developers	X	X	X	
Other Non-timber Forest Product Users	X			
Public NRM				
Tourism	X	X		
Recreation	X	X		
Conservation		X		
Fire Management for Life and Property		X		

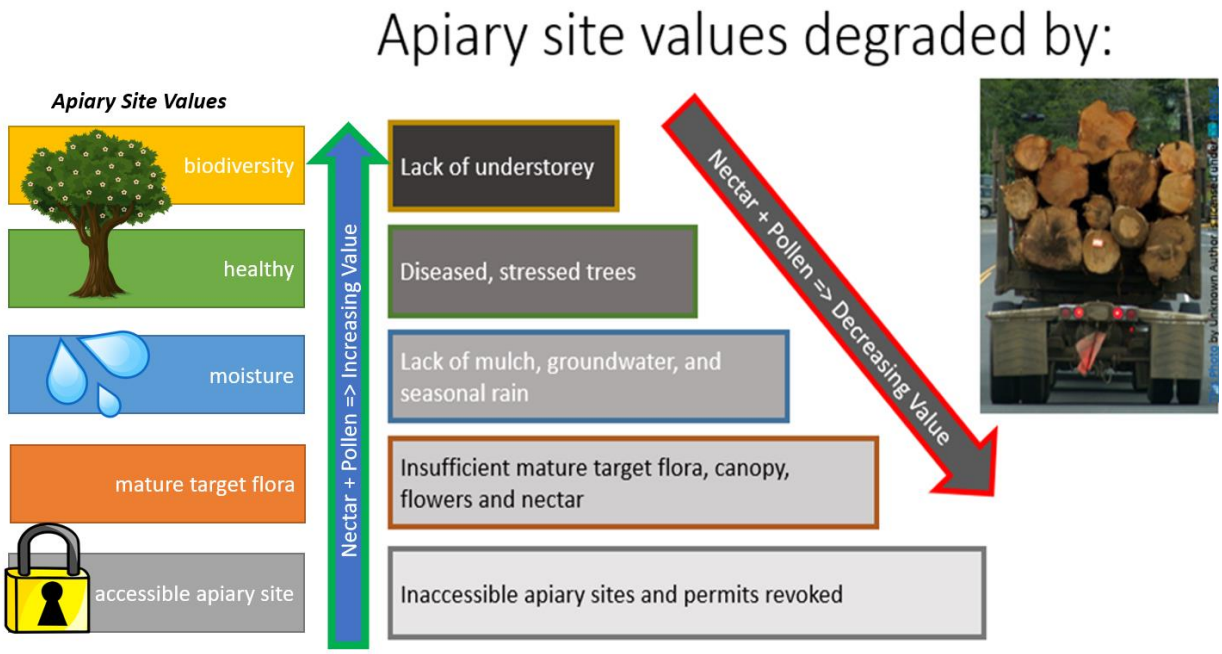


Figure 20: Apiary Site Values: Changes in attributes which decrease the value of an apiary site

Implications

The causes of commercial beekeeper resource insecurity on public lands in southwest WA are many and complex. This research has made the case that

1. commercial beekeepers operate within a complex system that spans many typically siloed areas of (natural resource) governance, (ecological) knowledge and (livelihood) practice (Q1);
2. beekeeping practices produce local ecological knowledges of 'apiary site values' unique to the industry (Q2)
3. commercial beekeeper livelihoods have co-evolved with their resource base, a reflection of the impacts of past and present competing interests and NRM policy and practices (Q3)
4. the cumulative effect of disturbances (both environmental and anthropogenic) has negatively impacted ecosystem health and site-specific 'apiary site value' which is a key driver of resource insecurity (Q4).

Beekeeper Resource Insecurity: The main drivers of beekeeper resource insecurity are access to quality sites (restrictions resulting from competing interests and resource management) and declining 'apiary site value' is impacting overall productivity.

Environmental Values: 'Apiary site values' (mature target flora, moisture, health and biodiversity) support the reproductive health of native flora and fauna. The cumulative impact of disturbance regimes combined with climate change decreases resilience to future shocks. Declining 'apiary site values' are reflective of a decline in environmental health and associated productivity.

Local Ecological Knowledges: Beekeepers possess holistic local ecological knowledges gained through decades of environmental observation and feedback from honeybee productivity. This knowledge can contribute to a better understanding of environmental change now and into the future.

Natural Resource Management and Governance: In broad terms, the objectives of state environmental agencies are shifting from sustainable forest management to ecosystem health (Burrows et al., 2022). Beekeepers are highly reliant on, and knowledgeable about the health of the local environment. Building relationships between the industry and natural resource managers could therefore result in enhanced ecosystem health.

Stewardship: Beekeeper 'apiary site values' reflect a healthy ecosystem that is more likely to be resilient in the face of climate change. It also supports numerous Sustainable Development Goal outcomes including food security (Patel, Pauli, et al., 2020). Beekeepers are motivated stewards of the environment and through co-production of knowledge with resource managers, 'apiary site values' can be enhanced resulting in better environmental outcomes overall.

To this end, the beekeeping industry of WA provides a valuable case study for considering how stakeholders can develop more collaborative relationships and bring together shared knowledges that enhance environmental stewardship.

Conclusions and Recommendations

The framing of beekeeper resource insecurity in relation to systems, sustainable livelihoods, historic and environmental change, provides a scaffolded approach for developing an understanding of resource insecurity in a range of environmentally dependant livelihoods. Here, we advocate for the beekeeping industry to foster a relationship with land managers that seeks to develop their agency as stewards of native floral resources through collaboration and understanding. Ways this may be achieved include:

1) environmental stewardship promotion as a core value of the beekeeping industry

2) policies and strategy development that engages the industry in a collective to improve relationships with land managers that draw upon the rich ecological knowledge of WA's beekeepers

3) a framework for data collection and sharing is developed that allows for an examination of the impact of disturbance regimes on apiary site values and use this information to provide appropriate and timely feedback to natural resource managers to aid in decision making processes.

4) resource managers are trained in the *B-Harmony* methodology (or similar) to build strong positive relationships with all stakeholders to enhance the ecological health of the State's natural resources.

To progress this research and develop appropriate resources in other states of Australia

5) similar research in each Australian state is conducted where resource insecurity is a concern for commercial beekeepers

6) state based networks of appropriately trained resource policy officers (independent of beekeepers) foster relationships between the beekeeping industry's key knowledge holders and relevant land managers in order to promote environmental stewardship and protect 'apiary site values'

To develop a nationally consistent approach to resource insecurity

7) a consistent policy position based on beekeeping values is developed. Australian Honeybee Industry Council (AHBIC) use this when communicating with relevant government bodies, private landowners and the general public about the state of the environment from a beekeeper's perspective.

References

Allan, L. F., & Manning, R. J. G. (1992). *Beekeeping in Western Australia* (Bulletin 4159, Vol. 10). Western Australian Department of Agriculture.

Allison, H. E., & Hobbs, R. J. (2004). Resilience, adaptive capacity, and the 'lock-in trap' of the Western Australian agricultural region. *Ecology and Society*, *9*(1). https://doi.org/10.5751/ES-00641-090103

Ayre, B. M., Roberts, D. G., Phillips, R. D., Hopper, S. D., & Krauss, S. L. (2020). Effectiveness of native nectar-feeding birds and the introduced Apis mellifera as pollinators of the kangaroo paw, Anigozanthos manglesii (Haemodoraceae). *Australian Journal of Botany*, *68*(1), 14. https://doi.org/10.1071/BT19097

Bargańska, Ż., Ślebioda, M., & Namieśnik, J. (2016). Honey bees and their products: Bioindicators of environmental contamination. *Critical Reviews in Environmental Science and Technology*, *46*(3), 235–248. https://doi.org/10.1080/10643389.2015.1078220

Bhandari, S. K., Veneklaas, E. J., McCaw, L., Mazanec, R., Whitford, K., & Renton, M. (2020). Effect of thinning and fertilizer on growth and allometry of Eucalyptus marginata. *Forest Ecology and Management*, *479*(September 2020), 118594. https://doi.org/10.1016/j.foreco.2020.118594

Birtchnell, M. J., & Gibson, M. (2006). Long-term flowering patterns of melliferous Eucalyptus (Myrtaceae) species. *Australian Journal of Botany*, *54*(8), 745. https://doi.org/10.1071/bt05160

Blyth, J. (Ed.). (1987). *Beekeeping and Land Management*. Department of Conservationand Land Management (CALM).

Burrows, N., Baker, P., Harper, R., & Silberstein, R. (2022). *A report on silvicultural guidelines for the 2024- 2033 Forest Management Plan to the Western Australian Department of Biodiversity, Conservation and Attractions*.

Campbell, T., Dixon, K. W., Dods, K., Fearns, P., & Handcock, R. (2020). Machine Learning Regression Model for Predicting Honey Harvests. *Agriculture*, *10*(4), 118. https://doi.org/10.3390/agriculture10040118

Chapman, N., & Oldroyd, B. (2019). *A Report to the Queensland Parks and Wildlife Service on the effects of commercial honeybees on native flora and fauna* (pp. 1–33).

Christensen, P. (1971). The purple-crowned lorikeet and eucalypt pollination. *Australian Forestry*, *35*(4), 263–270. https://doi.org/10.1080/00049158.1971.10675560

Clarke, M. A. (2020). *Strategic Industry Workshop: Improving floral resource access for beekeepers* (Issue January).

Coh-Martínez, M. E., Cetzal-Ix, W., Martínez-Puc, J. F., Basu, S. K., Noguera-Savelli, E., & Cuevas, M. J. (2019). Perceptions of the local beekeepers on the diversity and flowering phenology of the melliferous flora in the community of Xmabén, Hopelchén, Campeche, Mexico. *Journal of Ethnobiology and Ethnomedicine*, *15*(1), 1–17. https://doi.org/10.1186/s13002-019-0296-1

Conservation Commission of Western Australia. (2013). *Forest Management Plan 2014-2023*. Conservation Commission of Western Australia.

Couvillon, M. J., & Ratnieks, F. L. W. (2015). Environmental consultancy: Dancing bee bioindicators to evaluate landscape 'health'. *Frontiers in Ecology and Evolution*, *3*(MAY), 1–8. https://doi.org/10.3389/fevo.2015.00044

Crane, E. (1999). Chapt 35 History of Migratory Beekeeping. In *The World History of Beekeeping and Honey Hunting* (pp. 347-).

Day, C., & White, B. (2022). *A survey dataset to better understand the honey bee industry, use and value of natural resources and challenges for beekeepers in Western Australia: A beekeepers' perspective*. The University of Western Australia. https://research-repository.uwa.edu.au/en/datasets/a-survey-dataset-to-better-understand-the-honey-bee-industry-use-

DBCA. (2019). *Extending the Regional Forest Agreement for the South-West Forest Region of Western Australia: Overview of Stakeholder Engagement, November 2018: Vol. March*. Western Australian Department of Biodiversity, Conservation and Attractions.

Delnevo, N., Van Etten, E. J., Clemente, N., Fogu, L., Pavarani, E., Byrne, M., & Stock, W. D. (2020). Pollen adaptation to ant pollination: A case study from the Proteaceae. *Annals of Botany*, *126*(3), 377–386. https://doi.org/10.1093/aob/mcaa058

Department of Climate Change, Energy, the Environment and Water. (2022, September 22). *Tuart (Eucalyptus gomphocephala) Woodlands and Forests of the Swan Coastal Plain ecological community*. Species Profile and Threats Database. https://www.environment.gov.au/cgi-bin/sprat/public/publicshowcommunity.pl?id=153&status=Critically+Endangered

Department of Primary Industries and Regional Development. (2022, May 17). *Hive five for bee research and protection during World Bee Day*. https://www.agric.wa.gov.au/news/media-releases/hive-five-bee-research-and-protection-during-world-bee-day

Diaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J. R., Arico, S., Bartuska, A., Baste, I. A., Bilgin, A., Brondizio, E., Chan, K. M. A., Figueroa, V. E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., … Zlatanova, D. (2015). The IPBES Conceptual Framework—Connecting nature and people. *Current Opinion in Environmental Sustainability*, *14*, 1–16. https://doi.org/10.1016/j.cosust.2014.11.002

Diaz, S., Demissew, S., Joly, C., Lonsdale, W. M., & Larigauderie, A. (2015). A Rosetta Stone for Nature's Benefits to People. *PLOS Biology*, *13*(1), e1002040. https://doi.org/10.1371/journal.pbio.1002040

Dixon, D. J., Callow, J. N., Duncan, J. M. A., Setterfield, S. A., & Pauli, N. (2021). Satellite prediction of forest flowering phenology. *Remote Sensing of Environment*, *255*, 112197. https://doi.org/10.1016/j.rse.2020.112197

Farr, J. D., Wills, A. J., Van Heurck, P. F., Mellican, A. E., & Williams, M. R. (2011). Forestcheck: The response of macro-invertebrates to silviculture in jarrah (Eucalyptus marginata) forest. *Australian Forestry*, *74*(4), 315–327. https://doi.org/10.1080/00049158.2011.10676375

Ford, H. A., & Paton, D. C. (1986). *The Dynamic partnership: Birds and plants in Southern Australia* (H. A. Ford & D. C. Paton, Eds.). Government Printer.

Ford, H. A., Paton, D. C., & Forde, N. (1979). Birds as pollinators of Australian plants. *New Zealand Journal of Botany*, *17*(4), 509–519. https://doi.org/10.1080/0028825X.1979.10432566

Galbraith, S. M., Hall, T. E., Tavárez, H. S., Kooistra, C. M., Ordoñez, J. C., & Bosque-Pérez, N. A. (2017). Local ecological knowledge reveals effects of policy-driven land use and cover

change on beekeepers in Costa Rica. *Land Use Policy*, *69*(May), 112–122. https://doi.org/10.1016/j.landusepol.2017.08.032

Gill, R. (1996). *The Benefits to the Beekeeping Industry and Society from Secure Access to Public Lands and their Melliferous Resources.* (Issue August, p. 52). Honeybee Research and Development Council of Australia.

Gioia, P., & Hopper, S. D. (2017). A new phytogeographic map for the Southwest Australian Floristic Region after an exceptional decade of collection and discovery. *Botanical Journal of the Linnean Society*, *184*(1), 1–15. https://doi.org/10.1093/botlinnean/box010

Hamilton, T., Wittkuhn, R., & Carpenter, C. (2009). Creation of a fire history database for southwestern Australia: Giving old maps new life in a Geographic Information System. *Conservation Science Western Australia*, *7*(2), 429–450.

Hopper, S. D. (2021). Out of the OCBILs: New hypotheses for the evolution, ecology and conservation of the eucalypts. *Biological Journal of the Linnean Society*, *133*(2), 342–372. https://doi.org/10.1093/biolinnean/blaa160

Hopper, S. D., & Gioia, P. (2004). The Southwest Australian Floristic Region: Evolution and Conservation of a Global Hot Spot of Biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, *35*(1), 623–650. https://doi.org/10.1146/annurev.ecolsys.35.112202.130201

House of Representatives Standing Committee on Primary Industries and Resources. (2008). *More Than Honey: The future of the Australian honey bee and pollination industries* (Issue May).

Huutoniemi, K., & Tapio, P. (2014). *Transdisciplinary Sustainability Studies: A Heuristic Approach.* (Petri. Tapio, Ed.). Taylor and Francis.

Law, B., Mackowski, C., Schoer, L., & Tweedie, T. (2000). Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales. *Austral Ecology*, *25*(2), 160–178. https://doi.org/10.1046/j.1442-9993.2000.01009.x

Low, T. (2014). *Where song began: Australia's birds and how they changed the world*. Penguin Books.

Manning, R. (1992). *Honey Production, economic value and geographical significance of apiary sites in Western Australia: Final report (from a natural resource questionnaire for beekeepers)*. Western Australian Department of Agriculture.

McCaw, W. L. (2011). Characteristics of jarrah (Eucalyptus marginata) forest at FORESTCHECK monitoring sites in south-west Western Australia: Stand structure, litter, woody debris, soil and foliar nutrients. *Australian Forestry*, *74*(4), 254–265. https://doi.org/10.1080/00049158.2011.10676370

McCaw, W. L., Robinson, R. M., & Williams, M. R. (2011). Integrated biodiversity monitoring for the jarrah (Eucalyptus marginata) forest in south-west Western Australia: The FORESTCHECK project. *Australian Forestry*, *74*(4), 240–253. https://doi.org/10.1080/00049158.2011.10676369

Myers, N., Mittermeier, R. A., daFonseca, G. A. B., Kent, J., & Mittermeier, C. G. (2000). Biodiversity Hotspots for Conservation Priorities. *Nature*, *403*(6772), 853–858.

Orians, G. H., & Milewski, A. V. (2007). Ecology of Australia: The effects of nutrient-poor soils and intense fires. *Biological Reviews*, *82*(3), 393–423. https://doi.org/10.1111/j.1469-185X.2007.00017.x

Ostrom, E. (2009). A General Framework for Analysing Sustainability of Social-Ecological Systems. *Science*, *325*(5939), 419–422. https://doi.org/10.1126/science.1172133

Patel, V., Biggs, E. M., Pauli, N., & Boruff, B. (2020). Using a social-ecological system approach to enhance understanding of structural interconnectivities within the beekeeping industry for sustainable decision making. *Ecology and Society*, *25*(2). https://doi.org/10.5751/es-11639-250224

Patel, V., Pauli, N., Biggs, E., Barbour, L., & Boruff, B. (2020). Why bees are critical for achieving sustainable development. *Ambio*. https://doi.org/10.1007/s13280-020-01333-9

Prendergast, K. S., & Ollerton, J. (2021). Impacts of the introduced European honeybee on Australian bee-flower network properties in urban bushland remnants and residential gardens. *Austral Ecology*, aec.13040. https://doi.org/10.1111/aec.13040

Robinson, R. (2012). *The FORESTCHECK project: Integrated biodiversity monitoring in jarrah forest. Information Sheet 50/2012*.

Salvin, S. (2015). *Compatibility of Management Objectives on Public Lands with Beekeeping* (Issue 15/024). Rural Industries Development Corporation, RIRDC.

Smith, F. G. (1969). *Honey plants in Western Australia* (Bulletin No. 3618; p. 82). Department of Agriculture and Food. https://www.bicwa.com.au/_files/ugd/6b67c9_ca6e42e5dbdf4428a3612295ad434db9.pdf

Somerville, D. (1998). State Forests—A Valuable Beekeeping Resource. *The Australasian Beekeeper*, *100*(3), 96–101.

Somerville, D., Rural Industries Research and Development Corporation (Australia), New South Wales, & NSW Agriculture. (2000). *Floral resource database for the NSW apiary industry: February 1996 to June 1999*. NSW Agriculture.

Tobias, S., Ströbele, M. F., & Buser, T. (2019a). How transdisciplinary projects influence participants' ways of thinking: A case study on future landscape development. *Sustainability Science*, *14*(2), 405–419. https://doi.org/10.1007/s11625-018-0532-y

Tobias, S., Ströbele, M. F., & Buser, T. (2019b). Integrating scientific and local knowledge to address environmental conflicts: The role of academia. *Sustainability Science*, *14*, 405–419. https://doi.org/s11625-018-0532-y

WA Farmers Federation Beekeepers Section. (2017). *Tuart (Eucalyptus gomphocephala) woodlands and forests of the Swan Coastal Plain: Proposal to list as a nationally threatened ecological community. December*.

Watson, A., Judd, S., Watson, J., Lam, A., & Mackenzie, D. (2008). The Great Western Woodlands. *The Wilderness Society of WA Inx*, 80.

Williamson, J. (2015). *A history of inventory and the assessment of value in Western Australian Forests* (Issue April). Murdoch University.

Wills, R. T. (1989). *Management of the Flora Utilised by the European Honey Bee in Kwongan of the Northern Sandplain of Western Australia*. UWA.

Wills, R. T., Lyons, M. N., & Bell, D. T. (1990). The European honey bee in Western Australian kwongan: Foraging preferences and some implications for management. *Proceedings Ecological Society Australia*, *16*, 167–176.

Wyborn, C. A. (2015). Connecting knowledge with action through co-productive capacities: Adaptive governance and connectivity conservation. *Ecology and Society*, *20*(1). https://doi.org/10.5751/ES-06510-200111

Yates, C. J., & Hobbs, R. J. (1997). Temperate Eucalypt Woodlands: A Review of Their Status, Processes Threatening Their Persistence and Techniques for Restoration. *Australian Journal of Botany*, *45*(6), 949. https://doi.org/10.1071/BT96091