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2 Executive summary

Recent studies (C2013/188) highlight both the current decline and unrealised potential of beekeeping in Papua New Guinea (PNG), Fiji and Solomon Islands (SI). Beekeeping in these countries is facing major challenges with declining productivity and participation among smallholder beekeepers.

Activities undertaken as part of this SRA sought to strengthen existing partnerships, investigate the potential for improving women's participation in beekeeping enterprises, establish new methods for smallholders to manage mites in PNG and to conduct workshops and stakeholder meetings to inform the development of the full proposal to ACIAR.

The agreed outputs of this SRA include:

1. Report of meetings and travel including: an assessment of potential partners and their contribution to the project; an evaluation of the potential approaches to increase women's engagement in the honey bee industry; and, an update on the status of the bee industries in each country (included in this report);
2. A full funding proposal for a larger project completed (ACIAR Project LS/2014/042 awaiting final Country signoff);
3. Report describing pilot best-practice approach for the prevention and control of parasitic mites in PNG, Fiji and Solomon Islands (included in this report); and
4. A final report of all activities, outputs and outcomes up to the full project inception, including workshop with key stakeholders (this report).

In-country meetings, workshops and field days were undertaken with project partners in the Eastern Highlands Province, Simbu Province and Port Moresby in PNG, Vanua Levu and Viti Levu in Fiji and Honiara and Malaita in Solomon Islands between May-October 2018.

In the respective partner countries, the project team discussed and identified key challenges within the apiculture sector and developed research questions and desirable project outcomes that could help to overcome these constraints.

Supporting letters were provided from partner organisations and sign-off institutions identified as having national responsibility for the beekeeping industries. This included the Coffee Industry Corporation Limited (CIC) in PNG and Ministry of Agriculture and Fisheries (MAF) in Fiji. In PNG further partnerships have been created with National Department of Agriculture and Livestock (NDAL), Eastern Highlands Beekeeper Association, New Guinea Fruit Company, Mountain Honey and Oxfam International.

In Fiji, the Livestock Section of MAF, the Fijian Beekeepers Association and Biosecurity Fiji have all indicated a strong willingness to progress and implement discussed priority apiculture research objectives. The Australia-funded PARDI2 program was also identified as a partner in developing market chain aspects in Fiji that compliment technical beekeeping support of the proposed full proposal.

In-country meetings in PNG, Fiji and Solomon Islands identified that a full project should have the following objectives:

1. Develop and test appropriate technical, business and marketing practices for new and established bee-based businesses;

2. Improve control of diseases that constrain production and trade of bees, honey and other bee products; and
3. Build capacity of extension and development agencies to support beekeeping as a platform for sustainable small enterprises.

A honey bee mite (*Varroa and Tropilaelaps*) management experiment was conducted in the Eastern Highlands Province of PNG with CSIRO together with NDAL and CIC. The trial was developed in consultation with key apiculture staff with feedback from over 50 beekeepers from the Eastern Highlands Beekeeping Association during a stakeholder workshop. Three new non-chemical control methods were developed to overcome issues relating to increasingly high cost of the available acaricide product Bayvarol® and risk of mites developing pyrethroid resistance. The methods were developed to also enhance scaling up of bee enterprises by simultaneously facilitating increases in hive numbers and production of queen bees through complementary management techniques. The results of the study found numerous non-chemical control methods have the potential to effectively reduce mite numbers in honey bee hives. These methods all involve creating a brood-free period in hives, which showed greater effectiveness against *Tropilaelaps* because of its inability to feed on adult bees. Interestingly, the Bayvarol® treatment was less effective against *Tropilaelaps* than expected. This experiment highlighted that:

(1) creating a brood-free period in hives is an effective mite management strategy for smallholders;
(2) these methods are less effective for *Varroa* which may need additional management strategies; and
(3) current application of Bayvarol® was not providing the ‘near’ 100% mite knockdown expected for this product and likely needs optimisation for PNG conditions.

Empowering women through beekeeping and value-added bee products is an important focus of the full project proposal (LS 2014 042) (Figure 1). While beekeeping is an important income generating activity for many rural people in home gardens and houses in PNG, Solomon Islands and Fiji, the barriers limiting participation by women in these countries has been poorly understood.

A key element of this project, full proposal (LS-2014-042) for consideration by ACIAR, was refined during a workshop with project partners in August 2018 held at Southern Cross University. This workshop helped to focus the project aims and objectives and refined research questions and outputs. The development of the full proposal highlighted that both PNG and Fiji experience problems with pest and diseases management, queen rearing, genetic improvement, floral resource knowledge and access to beekeeping inputs and training and educational materials. Other problems include quality control in post-harvesting handling, limited market access and limited marketing of bee products.

Consultations with beekeepers in the Solomon Islands identified that the overriding issue affecting production was the invasion of the Asian honey bee (*Apis cerana*). In consultation with ACIAR staff it was evaluated that, despite this being a significant issue, it was tangential to the proposed project and would require a separate study to develop management protocols that was beyond the resources available at the time. A decision made in discussion with ACIAR to develop a separate project proposal for Solomon Islands was determined most suitable, given the time and resources allocation for the full proposal.

Figure 1: Entrepreneur beekeeper Miss Henao Longgar holding a nice frame of pollen.

3 Introduction

Beekeeping is an industry that provides the ability for economically marginalised groups, such as landless poor and rural women, to access income without exacerbating environmental and land tenure problems (Schouten & Lloyd, 2019). Honey bees have great potential to be developed as a smallholder niche industry with low input costs and the ability to scale-up quickly. Bee products can be marketed through existing networks and bees in many cases improve productivity of crop-farming systems through improved pollination.

Beekeeping in the Pacific Islands is under threat from limited technical beekeeping skills, inefficient queen breeding programs, increasing pests and diseases and quality control issues related to harvesting and post-harvest handling. These threats pose major risks to the vulnerability of smallholder beekeeping enterprises and also create biosecurity issues for the Australian honey bee industry, worth 6 billion annually (AHBIC, 2009; RIRDC, 2016).

Beekeeping in Fiji, PNG and Solomon Islands has been in decline, both in terms of overall production and participation rates for the past 40 years. Although these countries were once net exporters of most bee products, beekeeping is nowadays mainly a cottage industry, and current production is unable to meet local demand (ACIAR C2013/188, ACIAR C2015/079).

Recent ACIAR funded studies (C2013/188) have highlighted significant declines within the apiculture sector and also the unrealised potential of beekeeping enterprises in PNG, Fiji and Solomon Islands. These studies however, did not establish a process to address the challenges faced by the respective apiculture sectors. This SRA was developed to determine the current status of the industry and whether ‘best practice’ protocols for beekeeping could be established in the region. This SRA recognised the need for an establishment of partnerships and improved understanding of in country issues and opportunities in order to produce a full proposal with the following four main outputs:

1. Report of meetings and travel that includes: an assessment of potential partners and their potential contribution to the project; an evaluation of the potential approaches to increased women’s engagement in the honey bee industry; and, an update on the status of the bee industries in each country (included in this report);
2. To develop a full proposal to be submitted to ACIAR (ACIAR Project LS/2014/042 is awaiting final Country signoff);
3. Report describing pilot best-practice approach to the prevention and control of parasitic mites in PNG, Solomon Islands and PNG (included in this report); and
4. This Final Report to include all activities, outputs and outcome up to the full project inception, including workshop with key stakeholders (this document).

This SRA has developed partnerships that will underpin the full project and have determined the scope of the research, together with the resources and technical support required to undertake the research. This SRA also evaluated the potential for working simultaneously across the three countries and clarified further considerations for strengthening project focus.

Current situation of the beekeeping sector in Fiji
While no firm records exist, the north-western European dark bee (often called the German ‘black’ bee (*Apis mellifera mellifera*)) was believed to have been introduced by missionaries onto many Pacific Islands in the nineteenth century. While hardy, these bees were considered aggressive and to be poor producers when compared to the Italian strain

of honeybee (*Apis mellifera ligustica***)**. Driscoll (2009) reports that New Zealand aid programs in the 1970s and 1980s resulted in improved production through genetic improvement via the importation of Italian queens and targeted extension.

The Fiji beekeeping industry is currently based around the European honeybee (*Apis mellifera*) and is primarily smallholder based — there are a small number of semi-commercial and commercial beekeepers across the island chain. Beekeeping is predominately undertaken by farmers who use it to supplement and diversify their income. A few beekeeping operations keep enough hives to generate all of their income from beekeeping. Most beekeepers use honey as a sideline business, alongside other enterprises designed to help with family costs.

The Fiji honeybee industry operates in a highly favourable environment, until 2018 it was reported free of Asian bees (*Apis cerana*) and *Varroa* mites although outbreaks are now reported around Suva. Fiji appears free of many diseases and pests affecting neighbouring countries, with the exception of AFB (American Foul Brood). If AFB is controlled, this status change in biosecurity would allow access to a broad range of potential value added markets for Fijian bee products such as honey, propolis, wax and even queen bees if production levels can be raised. If *Varroa* becomes established then the use of miticides may affect access to the higher valued organic market for honey and wax. Honey is mainly consumed by the urban middle class who hold disposable income. At present the industry is yet to satisfy domestic demand for honey although viability could be threatened with importation of 'honey substitutes'.

The need for mite management strategies in PNG

The PNG beekeeping industry has strong potential to generate income for smallholder farmers and others along the value chain but has struggled to persist with increasing pest and disease pressures which have been identified as a major threat to the viability of the apiary industry. Recent studies highlight the significance of these threats, particularly in regard to *Varroa jacobsoni* (Anderson & Trueman, 2000; Roberts et al., 2015) and *Tropilaelaps mercedesae* mites (Delfinado-Baker & Aggarwal, 1987; Roberts & Simbiken, 2016; Anderson & Morgan, 2007). Earlier studies (C2015/079) in PNG on training and surveillance for *Tropilaelaps* mites in PNG highlighted that there were key features of the biology of *T. mercedesae* that indicated the possibility of eradication of *Tropilaelaps* in PNG. This was due to the fact that *Tropilaelaps* mites cannot use *A. cerana* as a host to facilitate its spread. Secondly, the mite cannot survive without feeding on *A. mellifera* brood for more than two days (Woyke 1987). The small size of the PNG industry was also a positive attribute in the feasibility of eradication with effective use of miticide strips and brood removal methods. Key informants from NAQIA and NDAL have since indicated that an eradication plan for *Tropilaelaps* was developed and funded by the Government of PNG through NAQIA. This was to be implemented in 2017, however introduction and spread of the coffee berry borer (*Hypothenemus hampei*) resulted in the redirection of funds to support its eradication and monitoring though the CIC and the eradication plan was terminated. Preliminary discussions with key informants highlighted an agreed mutual strategy to move from the notion of potential eradication toward management of *Tropilaelaps* and *Varroa*.

The combined stress of both species of mites has the potential to further reduce or eliminate the PNG beekeeping industry if not addressed. Personal observations and discussions with key informants, industry stakeholders and beekeepers suggest that significant hive losses and declines in hive numbers have occurred and that beekeepers are struggling to manage mite populations in their colonies (NDAL, 2017; NGF 2017; Oxfam, 2017, IHBA, 2017). Compounding issues of increasing prices for Bayvarol® chemical treatments to manage mites, limited educational materials and limited technical skills required to manage hives correctly is leading to significant colony losses. Beekeepers are reportedly either not treating their hives for mites which is having major impacts on honey productivity, or they are undertreating their hives (using less than the recommended application), which increases the risk of pyrethroid resistance developing to the only chemical currently available in PNG. Timing of treatments is also an issue for beekeepers, given there is currently little information regarding the timing, quality and quantity of floral resources available to bees. Where beekeepers are harvesting honey from bee hives during periods where Bayvarol® treatments are present (6-8weeks), there may be increased risks of contaminating honey which can negatively impact on the apiculture sector's reputation and ability to access export markets.

Currently the only mite management practice available in PNG is to use Bayvarol® strips which is a synthetic acaricide (active ingredient, flumethrin). No other non-chemical control mechanisms are being used, despite the need for alternative low cost and low risk management techniques for smallholder beekeepers. There is currently no information for mite population dynamics, which makes it difficult for extension agents and beekeepers to determine the most effective times to treat their hives. Other techniques such as making hive splits, artificial swarms and queen caging are all non-chemical control mechanisms that involve queen manipulation to create brood-free periods in a hive. Prior to this research, the effectiveness and suitability of these strategies for smallholder beekeepers was unknown. The effectiveness of these strategies may also differ for *Tropilaelaps* and *Varroa* populations because of their different biology. Ensuring there is adequate research will give confidence to extension officers in guiding beekeepers in new control practices. Further, these options need to use appropriate technology to improve uptake and overall management of mites. Improving options for beekeepers, and information to make informed management decisions, is urgently needed. This information is required to allow beekeepers to make decisions based on the cost, difficulty and effectiveness of different treatments, together with timing of treatments (when mite numbers are naturally high) and rotation of different treatments options to reduce acquired resistance developing.

Key informants also indicate there is increasing concern regarding a suspicious brood disease and stunted nurse bees with deformed wings, which can be indicative of European foulbrood (EFB) and deformed wing virus (DWV). Both these pathogens have not been reported from PNG and were not detected in the 2015 SRA C2015/079 but would have significant negative impacts on the honey bee industry. DWV in particular is a serious pathogen associated with *V. destructor* and *T. mercedesae* around the world and will influence the effectiveness and implementation of control strategies. The PNG Apiculture sector has highlighted a need for information to guide management practices to control *Varroa* and *Tropilaelaps* mites. The follow-on project LS/2014/042 should aim to provide information on *Varroa* and *Tropilaelaps* population levels at different time points in the year and training to help guide decisions on mite control strategies.

Opportunities for improving participation by women in beekeeping

Numerous studies (e.g. Pala 1974, Kaur and Sharma 1991, Ogaba 2002) highlight the importance of empowering women in achieving welfare outcomes in rural development, since a high proportion of cash income in the hands of women tends to be spent on family welfare. Income generated by beekeeping and value-adding bee products can be accessible to women, who rarely own land, have different assets, different access to resources, and different opportunities to men in the study area. With a narrower range of labour markets than men, diversification that improves the independent income-generating capacity of women also has the ability to improve family welfare (Bradbear 2009, Inder et al., 2013).

This SRA also conducted focus group discussions with key informants in PNG, Fiji and Solomon Islands in regard to current inclusion of women in apicultural enterprises and also perceived limitations to improving rates of participation. This study has highlighted there is much potential for improving beekeeping capacity for both women and youth in supporting inclusion and diversification among family small beekeeping business. No taboos were found to exist which forbid the involvement of women in beekeeping, and numerous positive comments were made support women's involvement, particularly when identified as a 'family enterprise'. A major concern raised was the need for training and extension support that was more inclusive of all family members. Accordingly, targeting the needs of women and families in various levels of the honey value chain, is a key focus for the partners in developing the full proposal. Passionate and skilled female beekeepers and queen breeders have been identified in both countries together with those focussed on women's empowerment in agricultural enterprises.

Overall need/significance of this SRA

These studies conclude that the viability of the industry is threatened, to a greater or lesser extent in each country, by hive management issues including: the need for effective pest and disease management; poor genetic base; a lack of understanding of nutritional needs and basic beekeeping skills; and limited access to hardware and appropriate technologies. Other issues of poor market access, cooperative management, and post-harvest handling compound these threats. Of particular concern is the potential for unmanaged pest and diseases in these countries (in particular *Tropilaelaps* and *Varroa*), to spread to, and severely impact upon, other Pacific Island countries and the Australian beekeeping industry. Based on previous studies it can be concluded that the industry is declining and faces serious threats, but there has been little guidance as to how to reverse the declining trend or counter the threats. Further research is required to elucidate these complex problems and answer the fundamental **research question:**

"What technical and development approaches are required to reverse the decline in the Pacific honey bee industry?"

A multidisciplinary strategy was required that embraces technical, business and social aspects. This involves the selection of appropriately skilled partners, especially those willing to investigate 'novel approaches' to reversing the decline in the Pacific honeybee industry. The possible solutions investigated included: improved biosecurity (particularly for parasitic mites and the non-native Asian honey bee *Apis cerana*); best practice beekeeping management practices for pest and disease control and supplementary feeding programs; adding value to honey, wax and propolis; and access to new and profitable markets. A strategy investigated in this SRA was the extent to which women and women's groups are currently involved in the beekeeping sector and the most profitable and suitable entry points for women along the value chain. For example, the modification of existing hive management practices and/or the introduction of value-adding technologies may help to improve access to income from beekeeping enterprises among women's groups.

Overall, the strategy for this SRA was to seek and establish partnerships with extension agencies, research institutions, beekeeping farmer groups and NGOs. The SRA process combined discussion among potential partners together with joint activity around the urgent issue of parasitic mite infestation in PNG.

The SRA and the full project align with ACIAR's program in the Pacific island countries to underpin the competitiveness and security of the agricultural sector (including forestry and fisheries). Honey bees are important pollinators for a variety of commercial and subsistence food crops and also provide primary or additional income to local beekeepers. The potential value of the industry is even higher now that there is a worldwide shift toward single-source varieties of honey and for honeys with medicinal values.

Previous ACIAR projects have laid the groundwork for understanding pest and disease management issues in the region and there is a need for research to develop strategies to deal with practical solutions for beekeepers and to address the biosecurity implications of these findings.

4 Aims and Objectives of Study

4.1 Aims

The aim of this study was to strengthen existing partnerships, investigate the potential for improving women's participation in beekeeping enterprises, establish new methods for smallholders to manage mites in PNG and to conduct workshops and stakeholder meetings to inform the development of the full proposal to ACIAR.

4.2 Objectives

1. Identify new and strengthen existing partnerships which are relevant to *Improving the bee industry in Fiji, Papua New Guinea and Solomon Islands* (completed);
2. Investigate the potential for women to fully participate in honey production and add value to existing and new bee products (included in this report);
3. Establish initial best practice guidelines for pest management of *Tropilaelaps* and *Varroa* mites for incorporation into extension and education materials (included in this report); and
4. Finalise the full proposal (LS-2014-042) for consideration by ACIAR (completed).

4.3 Outputs

1. Report of meetings and travel that includes: an assessment of potential partners and their potential contribution to the project; an evaluation of the potential approaches to increased women's engagement in the honey bee industry; and, an update on the status of the bee industries in each country (included in this report);
2. To develop a full proposal to be submitted to ACIAR (ACIAR Project LS/2014/042 is awaiting final Country signoff);
3. Report describing pilot best-practice approach to the prevention and control of parasitic mites in PNG, Solomon Islands and PNG (included in this report); and
4. This Final Report to include all activities, outputs and outcome up to the full project inception, including workshop with key stakeholders (this document).

5 Strengthening of existing partnerships and development of full proposal to ACIAR

To achieve the projects objectives (1 & 4) of strengthening existing partnerships and developing the full proposal to ACIAR, this study conducted in country visits and a preliminary socioeconomic and sociocultural assessment of the respective beekeeping industries in PNG, Fiji and Solomon Islands.

Site visits of farmers apiaries, beekeeping research stations, apiculture laboratories and honey processing facilities were undertaken to consider the existing situation in relation to honey bee health, role of honey in food security and livelihoods, opportunities and barriers to change, past and current experiences in honey production and options for development of a honey industry.

In addition to stakeholder meetings and discussions with institutional and community stakeholders', activities included inspections of hive designs and analysis of hive health, honey quality and pest and disease load.

This SRA also aimed to understand the limitations to building and strengthening local women's capacity to initiate and manage honey production and beekeeping input enterprises. Key informant interviews were conducted with project leaders from (ASEM/2010/052) in Canberra, Oxfam and Care in PNG and PARDI2 (AGB/2014/57) in Fiji, to get their perspectives on the gender inclusion approach to be taken by this project and work collaboratively with their key stakeholders. This was undertaken in the Eastern Highlands Province and Port Moresby in PNG, Vanua Levu and Viti Levu in Fiji and Honiara and Malaita in Solomon Islands between 10th May – 5th October 2018.

The engaged organisations had networks and experience in development of women's enterprises in the region and have become project partners for anticipated future projects. Semi structured interviews and focus group discussions were conducted with women who have commenced beekeeping projects and have either continued, or left the industry, to identify key issues related to success or failure of projects. The insights, priorities and feedback from these workshops, interviews and discussion has been incorporated into the full proposal design.

5.1 Southern Cross University partnership workshop

The full proposal for consideration by ACIAR was further developed from 20th-25th August 2018 during a workshop with the following key in country partners: CIC, NDAL, MAF Fiji, BAF at Southern Cross University. The workshop sought to engage all participants and in country partner organisations in inception planning, facilitation of cross border networking and to facilitate signoff of the full proposal. The workshop identified the key impacts desired of the project, formulated and selected appropriate research questions. The workshop also focused on strengthening partnerships in the development of an action plan and impact pathway that detailed roles and responsibilities, dates for commencement of project components and budgeting. The project proposal and impact pathway was developed in collaboration with key stakeholders, which involved:

1. Presentations by representatives on issues faced by the apiculture sector in each partner country;

2. The identification of key project impacts spanning scientific, capacity, social, economic, environment and policy impacts;
3. The development of key project objectives and research questions;
4. Identification of project activities, outputs and impacts; and
5. Identification and discussion on roles and responsibilities

Group discussions focused on how best to successfully scale up and ensure target community group adoption of the proposed collaborative research outputs. An important element of the workshop was in developing a culture of collegial dialogue between project scientists and field staff working at different scales.

During this SRA a workshop was held in August 2018 at Southern Cross University with key in country partners for planned future ACIAR research. This workshop was held to strengthen partnerships and further the development a full proposal to ACIAR *Improving the bee industry in Fiji, Papua New Guinea and Solomon Islands* AH/2014/042. The workshop highlighted that both Fiji and PNG have recently prioritised beekeeping as a way to complement smallholder incomes and to increase the participation of women without harming the natural environment with a 5% p.a. increase in production built into departmental KPIs. During the stakeholder workshop at SCU, the findings from meetings with beekeepers and key stakeholders in PNG and Fiji were refined to develop the specific objectives of the project proposal as:

- Develop and test appropriate technical, business and marketing practices for new and established bee-based businesses;
- Improve control of diseases that constrain production and trade of bees, honey and other bee products; and
- Build capacity of extension and development agencies to support beekeeping as a platform for sustainable small enterprises.

During the consultation process, (both in country and at SCU) a number of significant additional research questions outside of the scope of this project were identified. These include:

- What is the potential for domestication of *Apis cerana* for improving smallholder beekeeping enterprises in the tropics and for pollination security in north-eastern Australia?
- Does the integration of beekeeping into community coffee plantations increase the quality and quantity of coffee? (leading on from AH/2008/037 and in light of recent impacts on coffee yields resulting from the coffee berry borer incursion (*Hypothenemus hampei*)
- What are the returns on resource inputs for coffee in comparison to beekeeping enterprises?
- What are the key determinants influencing the success and failure of uptake among new smallholder beekeepers?
- What are the most effective strategies for smallholder beekeepers to manage *Apis cerana* in Solomon Islands?
- What is causing ‘disappearing disorder’ muck disease in Apis mellifera in Fiji and Australia?

5.2 Fiji

The project team, in collaboration with Fiji Partners, held a beekeeper workshop to discuss and identify solutions to key problems as identified by beekeeper stakeholders within the industry. Interviews, FGD's and workshops were conducted with the Biosecurity Authority Fiji, Fiji Ministry of Agriculture, Integrated Human Resource Development Program , Northern Development Program, Fiji Development Bank, Northern Beekeepers Association, Fiji Agromarketing and the Central Beekeepers Association. The project team also travelled to Taveune, Viti Levu and Vanua Levu to visit government research facilities, commercial and small-scale beekeepers and members of the Fijian Beekeepers Association (Figure 2; Figure 3).

The main issues identified were:

1. A poor understanding of nutrition among beekeepers, that led to overharvesting and consequently, inadequate food reserves for bees to survive the dearth;
2. No understanding of the need to requeen for youthful vigour or to improve genetics (many beekeepers reported that they had not seen a queen). Most could not make simple colony splits to increase hive numbers or replace failed hives;
3. Wooden hives tended to be untreated and in a poor state, often established in flood zones or not properly secured during the cyclone season;
4. Little traditional agricultural extension, government or NGO-sponsored training, or access to beekeeping books in any language; and
5. Basic business skills were lacking in record keeping, cash flow management, planning for equipment replacement, marketing and understanding of buyer preferences.

A number of technical issues face Fijian beekeepers, including: pest and disease (American Foul Brood and *Varroa* mite have recently been identified); inadequate supply of queen bees; poor nutrition; and management of genetics. From a socio-economic perspective there are a number of issues with the honey value chain and business development, training and support for new enterprises.

The Fiji Department of Agriculture maintains two small honeybee research centres — one at Batiri and the other at Dobuilevu. While intended to support queen breeding and colony improvement, in recent times these centres have focussed on the provision of nucleus colonies to beekeeping development programs dealing with the aftermath of Tropical Cyclone Winston (2016). Currently there is little genetic selection occurring. Neither beekeepers nor the queen breeding centres appear to be systematically selecting, evaluating and monitoring desirable traits and a significant opportunity to improve queen breeding programs and techniques exists.

Beekeeping is difficult in wet humid regions and therefore is focused in the drier regions found in the Western Division on Viti Levu and Northern Division of Vanua Levu of Fiji. Most Fijian beekeepers are small scale and do not keep enough hives to generate all of their income from beekeeping. Honey bees are considered a sideline, alongside other enterprises, to help with family costs. Government statistics indicate that there are approximately 1200 beekeepers registered, managing 12000 hives and producing 215 metric tons of honey. However, interview data, obtained as part of this research indicates that the 12 larger-scale beekeepers alone produce this figure and that there are around 805 smaller beekeepers, averaging 7 hives each, producing around 200 metric tons or nearly double the official estimate (Satish Narayan unpublished report to Ministry of Agriculture and Livestock 2018).

Official figures indicate average production of 22-25kg /hive with up to 40 kg/ hive achieved on some outer islands. While the figure of 1222 enterprises were recorded for 2014, the impact of Tropical Cyclone Winston and the subsequent relief efforts is still being assessed. At that time the average number of hives per enterprise was believed to be between 10-15. There are two harvests each year, one in May/June and the other in November/December. Most hives are static and only a few larger beekeeping operations migrate hives to take advantage of flowering events/nectar flows. All respondents reported a lack of drones between January and March indicating a dearth in nectar and pollen availability at this time.

Discussions with the President of the Fijian Beekeeping Association, (and confirmed by a number of larger scale beekeepers) indicated issues arising from a number of aid programs where many smallholders enter the industry without experience in beekeeping or adequate training and follow-up support. This observation was confirmed with direct observation and through discussions with small holders for this study. Issues faced by new beekeepers include:

- A poor understanding of nutrition, that led to overharvesting and consequently, inadequate food reserves for bees to survive the dearth;
- No understanding of the need to requeen for youthful vigour or to improve genetics (many beekeepers we met reported that they had not seen a queen bee). Most could not do simple colony splits to increase hive numbers or replace failed hives;
- Wooden hives tended to be untreated and in a poor state, often established in flood zones or not properly secured during the cyclone season;
- Mr Caldeira noted that most smallholders do not have the benefit of traditional agricultural extension, government or NGO-sponsored training, or access to beekeeping books in any language; and
- Basic business skills were lacking including— bookkeeping, cash flow management, planning for equipment replacement, marketing and understanding customers.

Our observations were that there needed to be two levels of training. Firstly, higher level training, including ‘train the trainer’ skills for staff from MAF, larger beekeeping operations, NGOs and BAF. Secondly, basic training targeted to new and existing beekeepers.

Figure 2: Doug Somerville Inspecting for brood disease in Fiji.

The Fiji Beekeepers Association provides beekeeping information and training in order to improve skill levels of beekeepers and conducts innovative mentorship programs to connect less experienced beekeepers with experienced mentors and has been particularly successful in encouraging women into beekeeping.

The Fijian Beekeepers Association report an excellent relationship with the Biosecurity Authority of Fiji and have worked closely with them on management of AFB programs. Our observation is, that the effective work that has been achieved to date with AFB control means that there is a real possibility to eliminate the disease in Fiji. Doing so would dramatically improve access to world markets for Fijian bee products.

Larger-scale, commercial beekeepers reported concern with poorly managed hives becoming a reservoir for pest and disease as a result of poorly trained recipients of grants. Other concerns were lack of access to private and government lands for bee sites, particularly in forest estates. This stops growth that, in turn, affects the ability to guarantee supply to potential offshore markets. While a premium price is currently being obtained for honey as a result of import restrictions, there is also a fear that increased supply and subsequent downward pressure on prices, may affect profitability of all players.

Figure 3: Apiary near Raki Raki, Fiji.

5.2.1 Issues with Supplementary Feeding of Bees in Fiji

During training carried out with the northern beekeepers an issue arose with the feeding of dry sugar to bees during the wet season. Standards suggest that white sugar should be fed, in either dry or liquid form, as molasses and brown sugar were known to be harmful. A number of respondents reported using remelt sugar, derived from collecting sugar on roadways around the plant, reprocessing it and selling on for animal production. The remelt sugar sells for considerably less than white sugar and was an attractive proposition until beekeepers started recording large-scale bee deaths associated with the feeding. A sample of remelt sugar was collected and compared with white sugar (Table 1). Levels of arsenic, lead and zinc were higher than the control however, further analysis is required to relate these findings to honey bee physiological impacts and colony health.

Table 1: Remelt sugar analysis

	Method	Lautoka Remelt Sugar April 2019	Control – White Sugar
	Job No.	*i2000/1*	*i2000/2*
Soil pH (1:10 water)	Rayment and Lyons 4A1	5.50	6.79
Soil Conductivity (1:10 water dS/m)	Rayment and Lyons 4B1	0.196	0.014
Silver (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.037	0.008
Arsenic (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	1.577	0.000
Lead (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.029	0.020
Cadmium (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.005	0.002
Chromium (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.069	0.061
Copper (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.219	0.028
Manganese (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.769	0.263
Nickel (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.003	0.042
Selenium (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.010	0.032
Zinc (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	4.5	0.4
Mercury (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.001	0.010
Iron (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	78.3	42.4
Aluminium (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	14.7	23.2
Boron (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.261	0.505
Silicon (acid soluble) (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	413	496
Vanadium (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.098	0.086
Cobalt (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.046	0.003
Molybdenum (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.014	0.000
Barium (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	0.171	0.143
Calcium (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	129	18
Magnesium (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	28	6
Potassium (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	235	13
Sodium (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	50	0
Sulfur (mg/kg)	1:3 Nitric/HCl digest - APHA 3120 ICPOES	103	21
Phosphorus (mg/kg)	1:3 Nitric/HCl digest - APHA 3125 ICPMS	11	0

5.3 Solomon Islands

The project team in collaboration with Solomon Islands partners held a beekeeper workshop in Honiara with over 50 participants, to discuss and identify solutions to key problems as identified by beekeeper stakeholders within the industry.

The beekeeping industry in the Solomon Islands is experiencing major declines in hive numbers and honey production over the past 20 to 30 years (Table 9). Currently the main constraints to the honeybee industry in the Solomon Islands are poor hive management and problems associated with Asian honeybees, which were first detected in the Solomon Islands in 2003. Limited access to beekeeping tools and equipment, a lack of extension services and poor beekeeper networking and inbreeding of the European honeybee stock have all contributed to poor colony health and productivity. Competition for floral resources by Asian honeybees, which was initially thought to be the most serious constraint to Solomon Islands beekeeping, is still a major issue despite the development of management methods for controlling Asian honeybees (PC/2004/030). A two-day workshop with key stakeholders revealed major colony losses sooner after the introduction of *A. cerana*. While earlier studies by Anderson (2004) and Agriculture staff have put this down to increased competition for floral resources and robbing by *A. cerana*. There may be another issue at work here as the descriptions, provided by beekeepers, of the speed of colony collapse, after *A cerana* is first seen on an island, are more indicative of the introduction of a new disease than competition for food resources. *Varroa jacobsoni* that was found to be reproducing on *A. cerana* do not appear to be breeding on European honey bees in Solomon Islands at this time, however the Asian honeybees do carry a form of nosema that can jump species. If this is the case, resistant genes need to be introduced into the population along with a breeding program and an understanding of nutritional needs to manage the situation (often pollen is fed to support infected populations). This and the management of *A. cerana* needs investigation but are beyond the scope of the proposed program. Beekeepers will need to be trained in the implementation of these new methods and a queen-breeding program implemented to improve genetic diversity and youthful vigor in Solomon Islands beehives. There is also a need for promotion of the beekeeping industry to both potential farmers and the consumers. Post harvest handling is a major issue in the tropics due to naturally higher moisture levels, but is exacerbated by harvesting unripe (uncapped) honey during the wet season when food and funds are scarce (Figure 4).

Figure 4: Hand crushing to extract honey in Gizo, SI.

In the two-day workshop, attended by 50 key informants, beekeepers reported the collapse of stocks when the Asian honey bee (*Apis cerana javana* – Indonesian haplotype) arrived (Figure 5). The arrival appears to coincide with the movement of logs from Bougainville, where barges carrying logs pass close to outlying islands in the Solomon group and equipment is moved between sites without biosecurity checks. *A. cerana* appears to be better suited to the conditions and climate of the Solomon Islands, out competing the European honey bee for the limited food resources available (during this study we witnessed the Asian bees entering healthy European honey bee colonies to rob their food reserves). Earlier studies by Anderson (2004) and Agriculture staff have cited increased competition for floral resources and robbing by *cerana*. While this appears to be the major contributing factor for the demise of the European honey bee, the rate of decline indicates the possible introduction of pathogens as another potential cause. The descriptions of the speed of colony collapse are more indicative of the introduction of a new disease than competition for food resources. The mites found on Asian honeybees do not seem to be breeding on the European bees in Solomon Islands, however the Asian honeybees do carry a form of nosema that can jump species. If this is the case, resistant genes need to be introduced into the population along with a breeding program and an understanding of nutritional needs to manage the situation (often pollen is fed to support infected populations).

On the few remaining islands in the Solomons that the Asian honey bee has not yet established itself, the European honey bee is more productive and successful. An example of this is the island of Simbo, which has gained certified organic status for the whole island. The Solomon Islands has quarantine restrictions on the importation of honey and bee products and is still free of many of the major pests and diseases. This is important to maintain as it will allow beekeeping to continue with the absence of diseases and pests such as American foulbrood, European foulbrood, *Tropilaelaps*, *Varroa* etc. With the reduced honey production and restrictions on imports the price of honey has risen and is quite expensive relative to many (Table 2) making the Solomon Island domestic market attractive for local apiarists.

Table 2: Solomon Islands annual honey production

Year	Annual Honey Production
1990s	140 tons p.a.
2000	90 tons p.a.
2010	40 tons p.a.
2018	4 tons p.a.

Many issues affecting PNG and Fiji beekeeping are present in the Solomon Islands. However, as the main issue impacting beekeeping in the Solomon Islands appeared to be the Asian honey bee that is now established on most of the Islands, and was outside the scope of this study, there appeared to be little value in incorporating the Solomon Islands into the larger program until a more comprehensive assessment of the impacts of the Asian honey bee could be undertaken.

Like beekeepers in Fiji and PNG, beekeepers in the Solomon Islands have limited access to information regarding floral resources and flowering times. A better understanding of beneficial plants for bees and floral calendars, would help local beekeepers understand and adjust their hive management to fit with seasonal nutritional surpluses and/or deficits. It may even prompt hive movements to exploit a range of floral resources available at different times of the year.

Queen bees are currently not being produced commercially in the Solomon Islands. This can limit the opportunity for optimising honey yields, reducing pest and disease pressures and potential industry expansion. It also limits selection for better suited genetic lines and, with low bee numbers in many locations, inbreeding can result leading to reduced production. To minimise this problem the importation of new genetic stock, queen bees, from Western Australia have been introduced with varying levels of success and at a substantial cost. Western Australian queens are used because of the low quarantine risk they pose.

Beekeepers need to be trained in the implementation of these new methods and a queen-breeding program implemented to improve genetic diversity and youthful vigor in Solomon Islands beehives. There is also a need for promotion of the beekeeping industry to both potential farmers and the consumers.
During focus groups and seminar discussions with the local beekeepers about the problems experienced with beekeeping in the Solomon Islands, the following recommendations were made:

1. **Develop a program to monitor and evaluate threats posed by *Apis cerana*, through competition and as a vector for disease, and develop management protocols.** While competition is a factor, the decline in *mellifera* populations appears to indicate that *cerana* may be acting as a vector for disease. Collection and analysis of samples, while outside the scope of this SRA, is recommended along with the development of management protocols applicable to the technology and resources available in-country.

2. **Eliminate Asian bee colonies.** Asian honeybees out compete the European honey bees for food reserves. By learning how to locate and destroy as many Asian bee colonies within the flight range of European honey bee colonies, beekeepers should increase the production potential. This task can also yield a wild harvest directly from the Asian honey bee colonies being destroyed by robbing the colonies honey and wax. Despite the Asian honey bee wax being slightly different to European honey bee wax, from initial research, it appears that Asian honey bee wax, when used for sheets of foundation, is readily accepted by European honey bees. With the high price being charged for honey in the Solomon Islands there would be no trouble in selling any honey collected by either honey bee type.

3. **Focus on bees wax production for export.** The price and demand for pure, “clean” (non-chemical contaminated) wax around the world is high and increasing with European, and United States supplies contaminated with miticide. Export restrictions for exporting wax are minor to non-existent and wax has a very long storage life making possible the accumulation and storage of wax allowing cost effective export methods to be used. The method for preparing wax for sale is easy and can be learnt quickly and achieved with low technology and financial input especially when compared to gaining export markets for food stuffs. Currently wax is usually discarded in the Solomon Islands but could be easily transformed into an export item.

4. **Honey production should focus on domestic supply only.** Honey in the Solomon Islands is very expensive relative to other countries around the world as quarantine restrictions provide import protection. With low levels of

production and high internal prices, the local market provides a premium price for honey that would be difficult to find internationally.

5. **Identify major exotic and endemic pest and disease threats and promote a secure quarantine system. Pest and disease identification and recognition training for beekeepers.** Being a country with many small islands, albeit close to known pest and disease 'hot spots', the Solomon Islands has the potential to restrict an incursion of an exotic pest or disease to one island or even eradicate from that one location. However, for this to happen beekeepers need to be able to quickly recognise what is not normal and inform the relevant authorities, so management actions can be taken. This could be an exotic pest or disease or even something that is endemic on other islands but has not yet been introduced to this area. With knowledgeable informed beekeepers the potential to limit the spread of a pest or disease throughout the island chain is increased.

6. **Identify the main floral resources and flowering times.** By knowing and understanding the flowering patterns of the floral resources and the nutritional value of these resources' beekeepers will be able to tailor their management practises to maintain hive health and maximise yields. Currently this knowledge throughout the Solomon Islands is limited. A compilation of this knowledge would be of great benefit to the industry.

7. **Develop and maintain a small queen rearing program to supply queen bees to the beekeeping industry.** A small queen breeding program could provide queen bees to the beekeepers of the Solomon Islands to help maintain hives with healthy young vigorous queens. Using queens for hive multiplication would enable quicker, more effective hive splitting while allowing for faster hive recovery. It would also be selective and choose the best-suited queen lines to breed from.

8. **Explore the possibility for propolis production.** Propolis is another potential money earner for beekeeper in the Solomon Islands. It would be interesting to see if there are any locations, floral resources or times of year when beehives in the Solomon Islands produced large quantities of propolis. If so, it could be readily collected, stored and exported around the world. Like wax it does not need expensive equipment or technical expertise to collect it. Propolis is a high value product that could be an additional income source for beekeepers.

The following is a brief outline of a program of activities and recommendations for improving capacity and productivity within the Solomon Islands honey industry.

Key priorities are to:

1. Improve quality and access to best practice bee husbandry practices through train the trainer programs with non-MAL service providers and identified NGO's;
2. Develop and evaluate strategies for effective management of *A. cerana;*
3. Investigate the potentials for low-cost local beekeeping input alternatives;
4. Develop appropriate training and educational materials to support queen breeders to produce improved quality and quantity of queen bees and nucleus colonies;
5. Investigate the potential for improving productivity of managed hives by implementing twice-yearly baiting of wild *A. cerana* colonies; and
6. Investigate appropriate supplementary feeding programs for improving colony survival and productivity through dearth periods during the wet season.

Figure 5: David Lloyd and Nick Annard with workshop participants at Honiara.

5.4 Papua New Guinea

Meetings and field days with beekeepers were conducted with the following stakeholder organisations in the Eastern Highlands Province (EHP) of PNG between May-June 2018 (Figure 6):

- Coffee Industry Cooperation (CIC)
- National Department of Agriculture and Livestock (NDAL)
- National Agriculture Research Institute (NARI)
- National Agriculture Quarantine Inspection Authority (NAQIA)
- Oxfam international in PNG (OiPNG)
- The University of Goroka (UOG)
- New Guinea Fruit Company (NGF)
- Eastern Highlands Mommas Safehouse
- CARE International in PNG
- AAAK Cooperative (Apo Angra Angna Kange)
- Eastern Highlands Beekeepers Association
- PNG Beekeeping Supplies
- Mountain Honey (Helping Hands Honey Producers – HHHP)
- Fresh Produce Development Agency (FPDA)
- ACIAR in PNG
- Henagaru Village Development Cooperative (HPDC)

Discussions with key informants highlighted a range of limitations and opportunities for progressing the apiculture sector with an estimated K2.1million annually in the EHP alone.

The key issues identified included:

- Honey processors are producing good quality honey, however further improvements in capacity to process honey and HACCP plans for safe food handling of honey is required to overcome issues relating to honey crystallisation and HMF to meet international CODEX standards should export markets be established;
- Limited financial capital to purchase honey and access to appropriate storage facilities, extraction equipment and packaging is also a challenge for honey companies;
- The NDAL have good beekeeping technical skills but are limited in extension and training capacity due to shortage of educational and training materials;
- The CIC have infrastructure and government support for the apiculture sector, however researchers and technical staff require assistance in the design, implementation and evaluation of beekeeping experiments to inform best practice;
- Beekeeping inputs suppliers are increasingly expanding their businesses, however prices remain high and there is a need to improve the capacity of numerous beekeeping businesses to supply quality beekeeping inputs to overcome high initial start-up costs and ensure affordable prices to smallholder beekeepers;
- Beekeepers are not value adding to their honey or processing beeswax, nor selling bee products in local markets. This highlights major opportunities for increasing income at the household level and for women to generate additional income through sales of honey at market where honey can be processed at the village level with support for ensuring appropriate post-harvest handling though networks at NDAL.

Figure 6: Cooper Schouten harvesting honey with beekeepers of Okapa District, Eastern Highlands Province PNG.

5.4.1 Smallholder Apiculture Stakeholder Workshop

Further strengthening between the project team and local beekeeping stakeholders was conducted to gain an understanding of the main challenges faced at the farmer level. The project team in collaboration with Oxfam, Mountain Honey, CIC, New Guinea Fruit Company and the NDAL held a smallholder beekeeper workshop at Goroka to discuss and identify solutions to key problems as identified by beekeepers within the industry.

A beekeeper workshop involving smallholder beekeepers was conducted in Goroka, PNG to discuss and identify solutions to key problems as identified by beekeeper stakeholders within the industry. The aim of the workshop was to identify key issues faced by beekeepers, to vote on which issues were core concerns to the industry and then identify solutions to these problems. A total of 125 beekeepers attended the one-day workshop (Figure 9; Figure 12). Participants came from 2 provinces, namely the Eastern Highlands Province and Jiwaka Province and 7 districts- Unggai/ Bena, Daulo, Henganoffi, Lufa, Okapa, Goroka and Lufa (Figure 7). The aim of the workshop was to identify key issues faced by beekeepers, to vote on which issues are core concerns to the industry and then identify solutions to these problems. A total of 119 male beekeepers and 26 female beekeepers were involved in separate discussion in regard to women’s involvement and limitations within beekeeping enterprises.

Participatory workshopping methods were used to encourage key industry partners to work together and problem solve in order to mediate discussion and problem solving by beekeepers and overall facilitation of the workshop. Beekeepers were involved in three main activities as outlined below:

Activity 1: Beekeepers were asked to write down their name, village, district, number of bee hives owned and to reflect, record and rank the three biggest beekeeping issues they were facing in order of importance. Weighted scores of 3 points to Issue 1, 2 points to Issue 2 and 1 point to Issue 3 was used to synthesise data collected. Key themes were then grouped into key issues to form priority action areas.

Activity 2: Beekeepers were split into groups from their respective districts and were asked to introduce themselves to their district group and share their beekeeping background and the issues they were facing. The district groups were then asked to select three core concerns as a group. Each group placed their three main issues on a wall and all groups participated in sorting these cards into key themes. Five key themes were discussed with all beekeepers and key informants from CIC, NDAL and local honey companies (Helping Hands Honey and New Guinea Fruit Co), worked together to facilitate this discussion.

All beekeepers were given two votes and were asked to vote on the five key themes on the wall. The results of this activity were tabulated, and discussion resumed between beekeepers and key informants. Further clarification of the five themes into sub-themes was conducted with 12 sub-themes identified. A two-point vote was conducted on these revised themes.

The 12 identified sub-themes were divided randomly among beekeepers who split into mixed district groups. The 12 groups were asked to develop an Action Plan to find solutions to the problems. The action plan had four components:

- The goal of the plan;
- The steps to achieving the goal;
- Who was required to be involved, and;
- When the key action dates were.

Activity 3: Groups were asked to present their action plan to the industry. Key informants facilitated this discussion and beekeepers gave their feedback, thoughts, concerns and ideas.

5.5 Findings from PNG smallholder beekeepers stakeholder workshop

Activity 1 – identifying priority issues for smallholder beekeepers
A total of 61 participants from 125 beekeepers who attended the workshop completed the first activity (Figure 9). Percentage response rates for the 61 beekeepers was 97%, 93% and 89% for Issue 1, Issue 2 and Issue 3 respectively. These 61 participants form the basis of the dataset for the results in Activity 1. Approximately 79% of participants were male and 21% were female. 83% of respondents answered the worksheets in English, while 16% wrote in Tok Pisin. No beekeepers from Kainantau or Obura-Wonenara districts participated in Activity 1, however it is believed beekeepers from Kainantau were present. The proportion of beekeepers from each district is presented in Figure 7.

When asked to reflect on their three biggest beekeeping challenges and place them in order of importance, a total of 29 different issues were identified (Table 3) Five core themes were identified including: improving costs and access associated with input supplies at 100 points: improved access to training and educational materials particularly in regard to queen breeding at 87 points: pest and disease management at 67 points: mechanisms for stabilising honey prices at 38 points: and improved access to extension services at 26 points (Table 3).

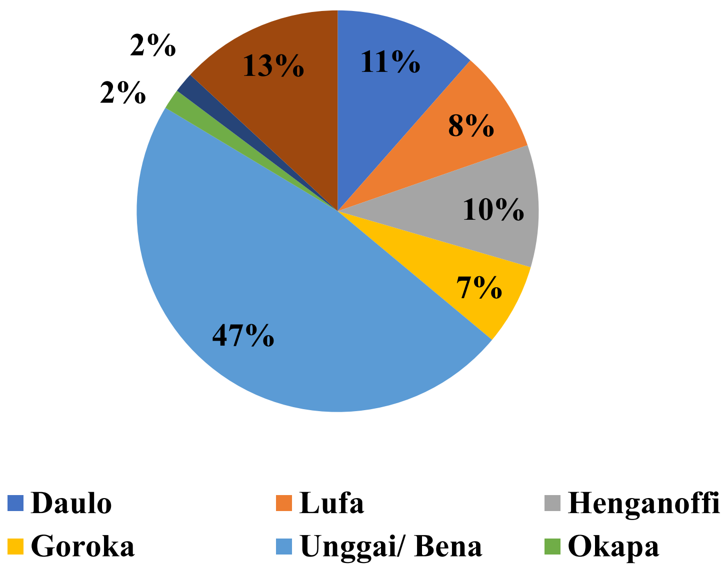


Figure 7: Proportion of beekeepers from respective districts.

Across the 7 EHP districts, beekeepers owned 14 bee hives on average. The highest mean number of hives per beekeeper was recorded in Daulo at 22 hives per beekeeper, followed by Lufa, Okapa and Henganoffi at 22, 18 and 12 hives per beekeeper respectively (Figure 8).

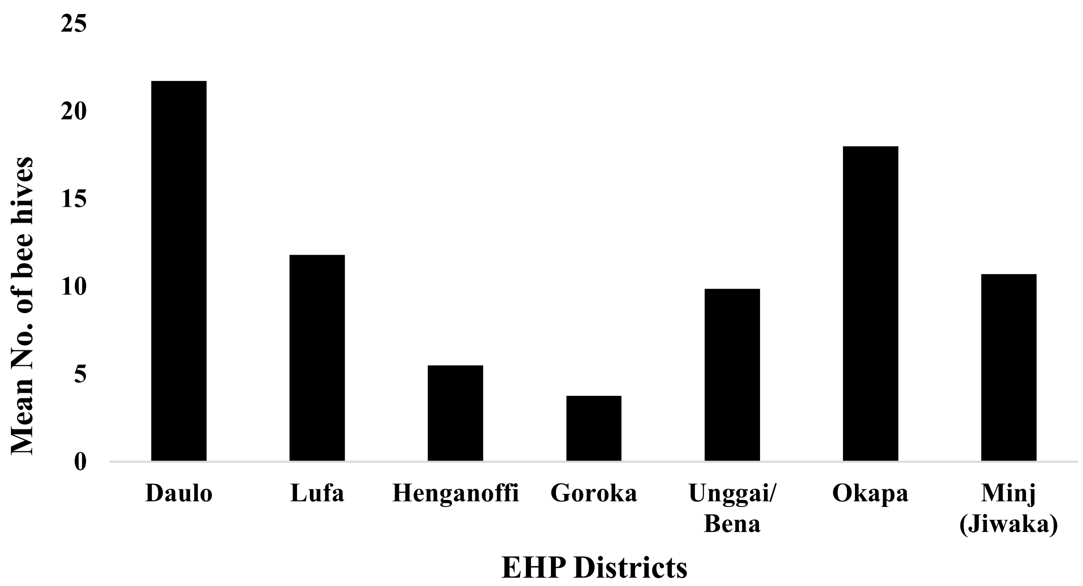


Figure 8: Mean number of hives per beekeeper in respective districts in the EHP.

Table 3: Identified issues and their weighted scores.

1. High price and access to beekeeping inputs	
High price of beekeeping inputs	73
Shortage of or access to materials	15
Broken extractor or requires one	9
Price of Bayvarol®	3
Total	**100**
2. Training and education	
How to make queen bees	28
More training needed	23
Help to check the bees (basic beekeeping skills)	20
Unproductive queen bees	6
High price of queen bees	2
Restart queenless colony	3
How to mark queen bees	1
How to make splits	3
New farmers difficult to gain experience	1
Total	**87**
3. Pest and disease management	
Pest/disease control (general)	26
Sick Bees (undistinguished)	25
Mites (undistinguished)	16
Total	**67**
4. Unstable honey prices	
Drop, low, instable honey price	38
Total	**38**
5. Extension support	

Inadequate Extension	11
Expert advice and supervision	5
Transport/ distance	6
Limited networking	4
Total	**26**
Other	
Marketing	6
Financial constraint/ assistance	5
Data system to record beekeepers information	3
Lack of government funding	3
Industry and farmer trends/info not available	2
Top bar hive	2
Burning of bee flora	2
No food for bees	2
Total	**25**


Figure 9: Smallholder beekeepers stakeholder workshop.

Activity 2 – identifying the three biggest challenges
One hundred and twenty-five participants divided into five groups to discuss major challenges and identified the three biggest challenges. Cards from each group were placed on a wall and sorted into five different categories by all stakeholders. These included: top bar hives (TBH); pest and disease management; beekeeping inputs;

marketing; and networking. These themes were subject to a democratic vote in which 80 beekeepers participated (Figure 10). This process identified the cost of inputs as the greatest issue facing beekeepers (57 votes), marketing as the second greatest issue (55 votes), which was strongly related to recent declines in prices paid for honey, networking (28 votes) and pest and disease management (16 votes). A concern for the use of TBH's relating to honey quality was also presented with 4 votes.

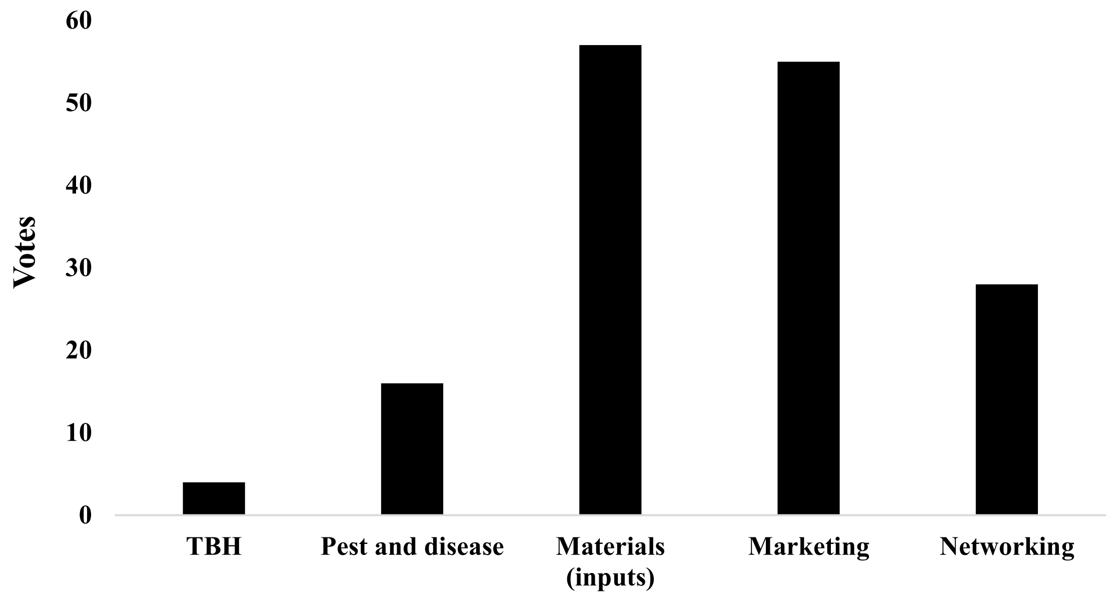


Figure 10: Core themes and voting tally for issues identified by beekeepers.

Core themes were then explored further through mediated group discussion to reveal the underlying issues into 12 sub-categories, for which another vote was conducted. The high costs associated with beekeeping inputs was identified as the single biggest challenge for beekeepers in the EHP with 34 votes. The second largest concern was that of low prices paid for honey at 33 votes, followed by issues within local beekeeping associations with 22 votes and limited beekeeper farmers groups at 21 votes (Figure 11).

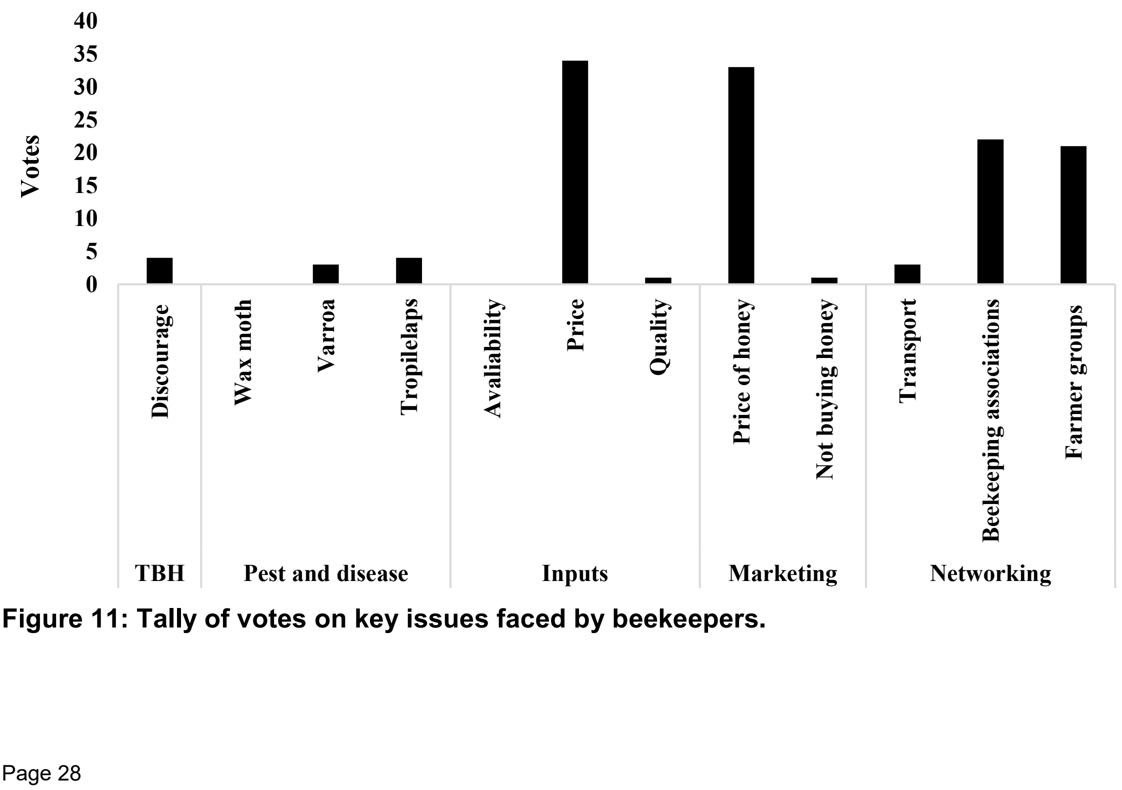


Figure 11: Tally of votes on key issues faced by beekeepers.

Figure 12: Beekeeper stakeholder workshop participants.

Workshop Discussion

The results of this workshop highlight various challenges faced by beekeepers in the EHP of PNG. A major challenge for beekeepers was that of increasing prices of beekeeping inputs to uptake or upscale beekeeping enterprises. Increasingly high prices for inputs appears to be the result of few competing business input suppliers.

Concerns regarding honey price instability and decline is likely to reflect a recent decision made by a leading honey company in the EHP who lowered the price paid for honey prior to the workshop. Discussions revealed the honey cooperative lowered the price due to unusually high honey production leading to supply exceeding processing capacity and financial capital to purchase honey. Another issue identified during discussions with honey packers and beekeepers during this workshop was that of insufficient funds to purchase honey resulting from the time delay for repayments to be made on honey sales to markets. Honey processors need support to ensure honey processing and purchasing can meet supply and so that beekeepers have a consistent market for their honey.

Issues related to queen bees revolved around the desire to learn how to make queen bees, unproductive queens and increasingly high prices for queen bees. Discussions highlighted a lack of training and support for smallholder beekeepers to learn this skill and educational materials and training was highly desired among beekeepers.

Interestingly, 16 beekeepers mentioned that mites were a specific pest and disease issue, however, 25 beekeepers indicated that their hives were ‘sick’ and a further 26 beekeepers indicated general pest and disease management as an issue. Beekeepers who indicated their bees were ‘sick’ were likely unable to discern the reason for their hives being sick. This highlights a range of understanding of current pest and disease issues among beekeepers and also a need for education and extension services to provide appropriate support for uptake of new and best practice pest and disease management strategies, specifically in regard to mites.

Beekeepers reported a desire to improve capacity for processing of honey at the village level through the development of farmers' groups. Discussions revolved around groups collaboratively financing extractors, straining equipment and containers. Limited access to funds to purchase extractors and support for ensuring sanitary post-harvest handling were discussed. Training for appropriate post harvest handling and food grade containers would be essential in this consideration.

Concerns regarding beekeeping associations were not discussed publicly and groups developing action plans for this topic were involved in group discussion but did not write down any of their concerns. Beekeepers may have felt they were unable to voice their opinion on this topic with key members from associations present. Future efforts to better understand some of these challenges may help to improve and tailor support services by associations for beekeepers.

It should be noted that while these issues reflect beekeepers' perceived major concerns, they are likely to vary through time in response to changes within the industry. For example, a jump in price paid for honey, a poor honey season and associated low productivity or another organisation making beekeeping inputs and therefore increasing competition and lowering input prices may lead to beekeepers reporting alternative issues as major concerns.

This workshop was facilitated by key stakeholders within the beekeeping industry who collaboratively showed great capacity for shared leadership and worked together to help beekeepers to discuss and describe their key issues and concerns. Strengthening of such partnerships and clarification of drivers governing decisions made within the industry may help to promote resilience, productivity and sustainability within the apiculture sector.

6 Improved strategies for smallholder honey bee mite management in PNG

The project team in collaboration with Oxfam, New Guinea Fruit Company and the Provincial Department of Agriculture and Livestock held a beekeeper meeting, involving over 60 beekeepers of the Eastern Highlands Beekeeping Association, Apiculture Officers of the NDAL and beekeeping technical staff from NGF and CIC (Figure 13). This meeting was conducted to discuss current mite management options and limitations faced by smallholder beekeepers and to explain and discuss the objectives of the mite trial being undertaken. Beekeepers highlighted that access to chemical strips to treat hives and finance to purchase them were major challenges to effectively managing their hives. Limited management of mites was reportedly resulting in significant colony losses and reductions in honey yields.

Beekeepers highlighted that both mite species were of significant concern and that increasing costs of Bayvarol® was a key constraint to managing mites and increasing productivity. There was encouraging interest and enthusiasm around the use of queen caging and similar strategies that disrupt the brood cycle to control mites.

Figure 13: Beekeeping mite management workshop at EHP Department of Agriculture and Livestock (DAL), PNG.

6.1 Methods for improved strategies for smallholder honey bee mite management in PNG

Collaborators for this research partnership were identified from, and by, the National Department of Agriculture and Livestock (NDAL), Coffee Industry Cooperation (CIC) and the Eastern Highlands Beekeeping Association (EHBA) in association with Dr John Roberts (CSIRO), Associate Prof David Lloyd and Mr Cooper Schouten (SCU). A Participatory Action Research approach to the mite management experiment was undertaken with key industry partners between May and October 2018 (Figure 14).

Suitable apiary sites and experimental hives were identified to investigate the effectiveness, cost and skill level required for (i) chemical and (ii) non-chemical control methods for smallholder management of *V. jacobsoni* and *T. mercedesae.* Chemical control used Bayvarol®, which is the only available product for beekeepers in PNG. Non-chemical controls used queen manipulations that interrupt brood production and hence disrupt the mite life cycle. Samples of adult bees and diseased brood were collected for screening for DWV and EFB.

A second trip in October 2018 was conducted to evaluate and facilitate the progress and completion of experiments and identify additional high priority research needs identified by apiculture industry stakeholders. Data for the mite experiment was collected and the analysis completed in country with partners from NDAL, CIC and the University of Goroka. Guest lectures and tutorials were conducted by Dr John Roberts and Mr Cooper Schouten at the University of Goroka for the purposes of capacity building within UOG's apiculture unit and dissemination of preliminary findings to agricultural research staff and students. Discussions of findings from the mite management research program were also conducted with key stakeholders from NDAL and CIC.

Figure 14: Mr Shayne Loie from CIC conducting brood uncapping and Mr Jonah Buka from NDAL caging queen.

The following methodology was used in order to answer the associated research questions:

1) How effective are the proposed mite management strategies against *Varroa jacobsoni* and *Tropilaelaps mercedesae* in PNG?

Two appropriate sites in the Lufa District of the EHP were identified in discussion with Apiculture Officers of the EHP NDAL for the purposes of the experiment (Figure 15). Sites were selected based on the following determined criteria:

- Convenient location for beekeeper to allow for continuous monthly monitoring;
- Owned by a beekeeper with proficient skills to carry out the ongoing experiment;
- More than 8 hives per site to enable at least two replicates of each mite management strategy (treatment); and
- Hives must not have been managed for mites (i.e. used Bayvarol®) in 2018 (5 months prior to experiment).

In addition to the above criteria for site selection, further selection criteria were used for identifying suitable bee hives to be used in the mite experiment:

- Hive must be a double or triple box;
- Colony must have an actively laying queen;
- Both *Varroa* and *Tropilaelaps* detected; and
- Hive must be free of brood disease (i.e. American foulbrood or sacbrood virus).

Colonies which met the experiment criteria were given a reference code. On day 1, sticky mats were placed in hives for 24 hours. On day 2, sticky mats were removed and initial *Varroa* and *Tropilaelaps* populations were recorded in each experimental hive using a combined method of four tests, namely sugar shake, uncapping of brood, bump test and sticky mat (SUBS). The full SUBS was used in May and again in September to establish initial and final mite populations. During the months of June, July and August sticky mats were used to monitor mite populations.

Figure 15: Site 1 of the mite management experiment.

6.1.1 SUBS identification and monitoring methods

Mite sampling methods used in this study have originally been designed and calibrated for monitoring *V. destructor*, not *V. jacobsoni* or *T. mercedesae*. These methods are also developed for use in temperate climates. This should be considered when interpreting the results of these methods for mite detection and monitoring. The following results from the four monitoring methods used in this study are presented below (Table 4).

Sugar-Shake method.

Sugar shaking is a sampling method used to detect *Varroa* mites in bee colonies (Dietmann *et al.* 2012) (Figure 16). Briefly, this involved collecting approximately 300 adult bees from the brood nest into a container with a mesh lid. Icing sugar was then added to the container to coat the bees. The container and bees were then shaken over a tray to dislodge and collect phoretic mites (Anderson & Roberts, 2013; Ellis 2000, Macedo & Ellis 2001). During this activity the sugar-shake method was used effectively, although there were problems for some hives with the icing sugar clumping if bees were collecting a lot of nectar. By using bees from frames with less nectar and performing tests earlier in the day we were able to minimise this problem. Having consistent sampling equipment and more training would also improve the use of this method for monitoring mite levels.

Figure 16: Mr Jonah Buka conducting a sugar shake test.

Uncapping brood method

Uncapping of brood cells using forceps was used effectively for detecting *T. mercedesae* and *V. jacobsoni* (Figure 17). This method is laborious but necessary as a high percentage of the mite population is present inside sealed brood cells (Anderson & Roberts, 2013). This technique is more time-consuming and was found to be less sensitive for detecting low mite levels. Key informants of this study indicate that this method is highly suitable for smallholder beekeepers to implement in their beekeeping routines to monitor mite populations.

Figure 17: Uncapping worker brood cells to find mites

Bump test

In addition to the uncapping of brood cells, the 'Bump Test' was used to estimate mite populations (Pettis *et al.,* 2013) (Figure 18). After uncapping of 50 brood cells, the frame was then firmly bumped over a tray two times, with mites dislodged into the tray for counting.

Figure 18: Mr Shayne Loie of CIC conducting a bump test.

Sticky-mat method

Sticky mats were used to determine 24-hour natural mite fall from May-September 2018 (Figure 19). A total of 180 sticky mats were used in the mite management experiment. Sticky mats were examined for mite counts during in country during visits in October 2018.

Figure 19: Labelled sticky mat being entered and after 24-hour natural mite fall.

Table 4: Advantages and disadvantages of monitoring methods for smallholder beekeepers in PNG.

Monitoring method	Advantages	Limitations
Sticky Mat	Low level of skill required by beekeeper	Labour intensive – 2 hive visits and analysing mats.
	Represents a good method for conducting surveys for monitoring distribution of mites i.e. for biosecurity staff (NAQIA).	Analysis of sticky mats requires good mite identification skills
	Represents a good method for estimating population fluctuations between seasons.	Access to sticky mats possibly unreliable and a significant cost
	Is a non-invasive and non-chemical monitoring method	Bees sticking to mat can concern beekeepers and makes mite identification more difficult.
	Most consistent method for targeting both mite species	
Bump Test	Is a non-chemical monitoring method.	Requires a tray to collect "bumped" mites.
	Low level of skill required by beekeeper	Not a sensitive method for mite detection at low

		population levels, particularly for *Varroa*
	Quick method	
	Low cost to the beekeeper and scalable for uptake among smallholder beekeepers	
Uncapping	Low level of skill required by beekeeper	Requires forceps or similar tool to uncap brood cells
	More sensitive method for *Tropilaelaps*	Uncapped brood dies
	Low cost to the beekeeper and scalable for uptake among smallholder beekeepers	Time intensive
	Is a non-chemical monitoring method	Not a sensitive method for mite detection at low population levels
Sugar Shake	Moderate level of skill required by beekeeper	Not as sensitive for detecting *Tropilaelaps*
	Is a non-chemical and non-lethal monitoring method	Time and resource investment to buy sugar and make a sugar shake jar may prove prohibitive to smallholder uptake
	Effective method for detecting *Varroa*	

6.1.2 Experimental design

The following protocol was implemented to determine initial and final mite populations in May and in October 2018:

a) Remove labelled sticky mat after 24hrs and seal in zip-lock bag;
b) Open hive and identify a frame of sealed brood, preferably with signs of ‘bald brood’ (symptom of *Tropilaelaps* infestation);
c) Shake adult bees into a tray and scoop out ~300 bees (1 cup) for sugar shake (2 tablespoons of icing sugar placed into jar with 3 mm gauze lid, rolled for 3 minutes then sugar and dislodged mites shaken out) over light-coloured tray;
d) Count and collect *Varroa* and *Tropilaelaps* mites in ethanol vial, record in data sheet;
e) Record number of bald brood cells on each inspected frame as either High, Medium or Low prevalence;
f) Record estimated number of honey, pollen and brood frames in hive;
g) Uncap and remove 5x10 rows of sealed worker brood with forceps on one side of brood frame and count infected cells. Repeat for other side (100 cells in total). Record in data sheet;
h) Bump each side of brood frame twice over tray and collect and record mites; and
i) Collect 50 adult bees in ethanol for pathogen screening.

Experimental hives were randomly assigned to a treatment/control group (see Table 5):

1. Untreated control (U); no mite management applied;
2. Bayvarol® strips (B); applied at recommended dosage rates of two flumethrin-impregnated strips per five frames of brood and removed after eight weeks;

3. Queen caging (QC); queen was located and caged within the hive to prevent egg laying until being released after 28 days;
4. Queen removal/Hive split (QR); queen was located and transferred to the 'artificial swarm' hive along with a proportion of the adult bees shaken off frames; Remaining bee population is left to raise a new queen, during which no eggs are laid for at least 28 days;
5. Artificial swarm (AS); a new hive box containing frames with only foundation received the queen and a sub-population of adult bees from a QR hive. Egg laying is prevented for several days until the bees can create suitable brood comb for the queen. Hive entrances were closed/blocked for 24 hours to reduce bees returning back to their original hives.

Table 5: Mite management experiment comparing a chemical treatment with three brood interruption strategies that could be used by PNG beekeepers. We had seven replicate hives for each treatment.

Day	Untreated control	Bayvarol®	Queen Caged	Queen Removal	Artificial Swarm
Day 1	Untreated	Two Bayvarol® strips per five brood frames	Queen caged within the hive to prevent egg laying	Queen transferred to new 'artificial swarm' hive. Hive raises a new queen.	Start with new box and foundation frames only. Shake in bees off 6-8 frames from 'queen removal' hive. Introduce queen collected from 'queen removal' hive. Block entrance for 24 hours.
Day 2					Unblock entrance
Day 7				Confirm presence of queen cells	
Day 28			Release queen from cage to allow egg laying	Check presence of laying queen	Check presence of laying queen
Day 56		Remove chemical strips			

A total of seven replicates for each treatment was established, with five at Site 1 and two at Site 2 (n=36 hives).

Sticky mats to estimate 24-hour natural mite fall were used every 4 weeks for 5 months (5 sticky mats per hive). Collected sticky mats were kept at 4˚C and then analysed under low magnification during the second visit in September. Total number of mites for both *Varroa* and *Tropilaelaps* were estimated and recorded in datasheets (Appendix 3).

A schedule was developed in order for part of the experiment to be undertaken by stakeholders from NDAL (Table 6). This aimed to strengthen project ownership and interest in outcomes of the research findings. It also aimed to identify the most suitable mechanisms for communicating with relevant project personnel between Australia and PNG in light of project communication efforts for the larger planned project. Frequent emailing, Facebook discussion group chats and phone calls were all used in communication between countries throughout this research trial.

Table 6: Schedule developed for DAL to ensure they know when and what needs to be done over the next months to complete the mite treatment experiment.

Date	Action
June 13th	Put sticky boards into GH hives
June 14th	Collect sticky boards from GH hives after 24 hours Release queens from GH queen cage hives (3, 11, 15, 19, and 22) Check GH queen removal hives are queen-right. Add mated queen if necessary. Put sticky boards into JH hives
June 15th	Collect sticky boards from JH hives after 24 hours Release queens from JH queen cage hives (2 and 5) Check JH queen removal hives are queen-right. Add mated queen if necessary.
July 12th	Put sticky boards into GH and JH hives Remove Bayvarol® strips from GH and JH hives
July 13th	Collect sticky boards from GH and JH hives after 24 hours
August 9th	Put sticky boards into GH and JH hives
August 10th	Collect sticky boards from GH and JH hives after 24 hours
September 6th	Put sticky boards into GH and JH hives
September 7th	Collect sticky boards from GH and JH hives after 24 hours

GH - George Waenavis hives JH - Jesse Yawanes hives

During this experiment the entrances of several AS hives were not effectively blocked for 24 hours, allowing bees to leave the new hive. As a result, these hives had smaller starting populations and had low colony strength. Because of this the AS treatment data was not representative of a successful colony build up was therefore excluded from analysis. Another artificial swarm that was made simultaneously to the mite management experiment was well established four months later. Although not monitored, a sugar-shake conducted on this hive in September found relatively high *Varroa* mites numbers (50 mites from 300 bees) and no *Tropilaelaps* mites.

Two QR hives failed to raise a new queen and were to be re-queened by NDAL, however, because no queen bees were available at this time these two hives were excluded from the analysis.

2) What are the seasonal population dynamics for *Varroa jacobsoni* and *Tropilaelaps mercedesae* in PNG?

Skilled beekeepers who had apiaries that met the abovementioned criteria were identified with NDAL through the EHBA. These beekeepers were trained in using sticky mats and were given five labelled sticky mats to use at 4-week intervals to record natural mite fall from untreated colonies. Sticky mats were returned to NDAL and analysed during the September visit. These beekeepers came from Daulo, Goroka, Bena and Lufa districts of the EHP.

3) Does DWV infect honey bees in PNG?

Adult bees were collected from experimental treatment hives and additional colonies of *A. mellifera* and *A. cerana* in the Highlands region in both May and September 2018. Samples were preserved in 70% ethanol and stored at -20°C until needed. Pooled samples of 30 bees tested for DWV strains by qPCR in Australia using published protocols (Kevill et al 2017).

4) Does European Foulbrood disease infect honey bee colonies in PNG?

Brood symptomatic of European foulbrood (EFB) was identified and collected from a hive at one of the experimental sites. European foulbrood (EFB) Diagnostic Test Kits™ (Vita Bee Health) were used to test three symptomatic larvae.

Statistical analysis of mite treatment experiment
Numbers of Varroa and Tropilaelaps mites in hives were estimated from the average number of mites from counted from three rows of the sticky board. This suitability of this estimation method was cross-checked and confirmed by counting the total mites counted on several sticky boards.

Mite treatment data was analysed in GraphPad Prism 7 using two-way ANOVAs to compare changes in log transformed mean mite numbers across treatments between June and September. Hives with initial mite numbers less than 10 were excluded from the analysis. Efficiency for each treatment at each time point was calculated using the geometric mean mite numbers and the equation; efficacy = (untreated mean – treated mean)/untreated mean x 100.

6.2 Results of mite management strategies against *V. jacobsoni* and *T. mercedesae* in PNG

Only the Bayvarol® treatment significantly reduced mean *V. jacobsoni* numbers compared to the untreated control hives and remained significantly lower from June to September (Figure 20).

These findings support the continued use of Bayvarol® to effectively reduce *V. jacobsoni* populations in PNG. While these methods reduced the amount of brood available to mites, the ability of *V. jacobsoni* to survive on adult bees for up to 4 weeks has likely limited the effectiveness of the queen cage and queen removal strategies. However, these methods did have an impact on *V. jacobsoni* and there was a trend for slower population growth under these strategies compared to the untreated hives.

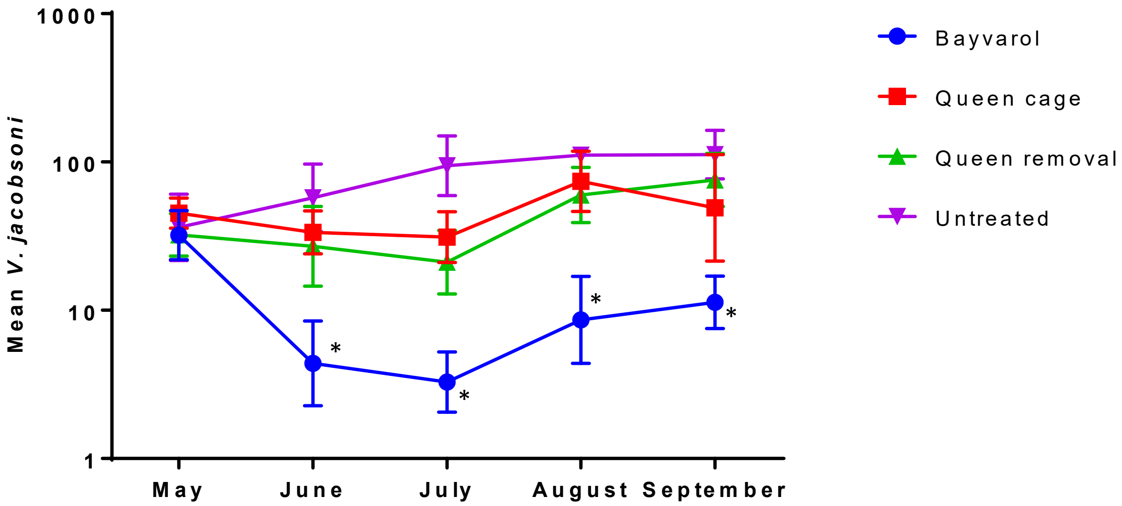


Figure 20: Average numbers of *Varroa jacobsoni* in hives before (May) and after treatment (June to September). * denotes a significant difference (P < 0.05) from the untreated control.

T. mercedesae numbers were significantly reduced by the queen cage treatment in June and July, and the queen removal treatment in July compared to the untreated control hives (Figure 21). These findings show that making hives brood-free can be a very effective strategy for reducing *T. mercedesae* populations in PNG, but the effects were unfortunately not sustained. The fast reproductive rate of *T. mercedesae* likely facilitated a rapid recovery, although reintroduction of mites from neighbouring untreated hives can also increase mite numbers more quickly. Mite treatments in practice, should be applied to all hives in an apiary to minimise the rate of reintroduction. Therefore, the brood manipulation strategies may offer longer control of *T. mercedesae* than observed in this trial.

Bayvarol® did not significantly reduce *T. mercedesae* numbers compared to untreated hives, although there was a trend for lower numbers. This finding is surprising as this chemical is reported to have high efficacy against *T. mercedesae* in Thailand (Kongpitak et al 2008). It is likely the behaviour of *T. mercedesae* has reduced the effectiveness of this contact acaricide as the mites spend little time on adult bees which come into contact with the chemical strips. The use of Bayvarol® or similar chemicals will need better optimisation to become effective strategies against *T. mercedesae*. For example, consolidating the brood to a single box with a queen excluder or combining treatment with a queen manipulation strategy may improve results.

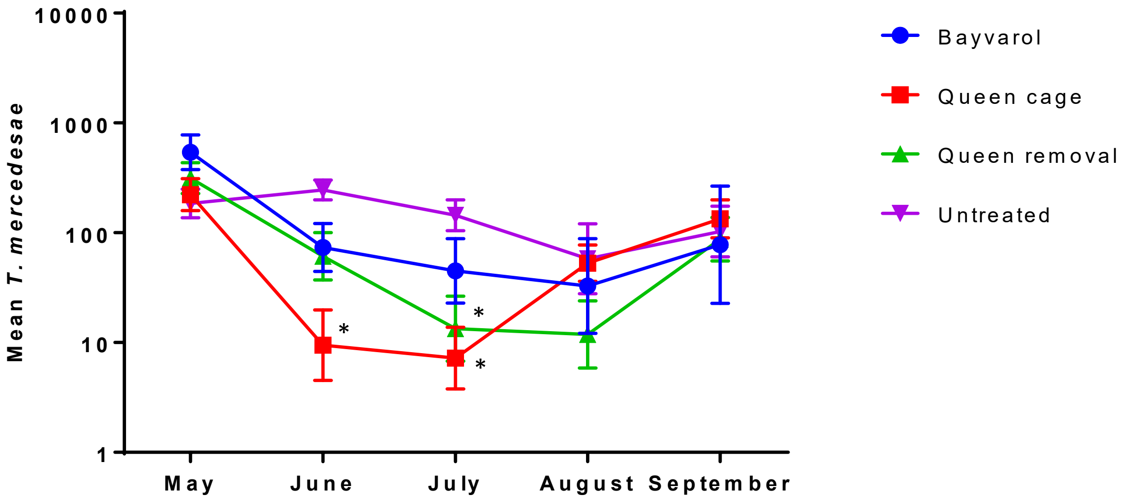


Figure 21: Average numbers of *Tropilaelaps mercedesae* in hives before (May) and after treatment (June to September). * denotes a significant difference (P < 0.05) from the untreated control.

The calculated efficacy of each treatment at each time point is shown in Table 7. The Bayvarol® treatment was the most effective control strategy for *V. jacobsoni*, maintaining high efficacy (>90%) through to September. Additional control strategies with high efficacy are still needed to avoid the development of resistance to Bayvarol®. At this stage, this will be another acaricide. The brood manipulation strategies had high efficacy against *T. mercedesae*, but were not sustained. The queen cage strategy was highly effectively in June and July, but dropped sharply. The queen removal strategy had a more delayed effect that gave 81% efficacy in August, but this too dropped sharply by September. It is likely that these strategies can be further optimised to achieve longer efficacy.

Table 7: Percentage efficacy of mite treatments for *V. jacobsoni* and *T. mercedesae.*

	Varroa jacobsoni			***Tropilaelaps merdecesae***		
	Bayvarol	Queen cage	Queen removal	Bayvarol	Queen cage	Queen removal
June	93 %	42 %	56 %	71 %	96 %	76 %
July	97 %	68 %	79 %	70 %	95 %	91 %
August	93 %	35 %	47 %	44 %	11 %	81 %
September	91 %	56 %	33 %	23 %	0 %	15 %

This research found that the different methods for estimating mite numbers (SUBS) found the sticky mat and all three other methods (sugar-shake, uncapping and bump test) were significantly correlated for both *V. jacobsoni* and *T. mercedesae* (Figure 22, Table 7). This means that while these methods differ in their sensitivity to detect low level mite infestations, these methods are still informative monitoring options for smallholders and are likely more affordable. It also means that these methods may be useful in detecting both species of mites within bee colonies should populations become established in Australia.

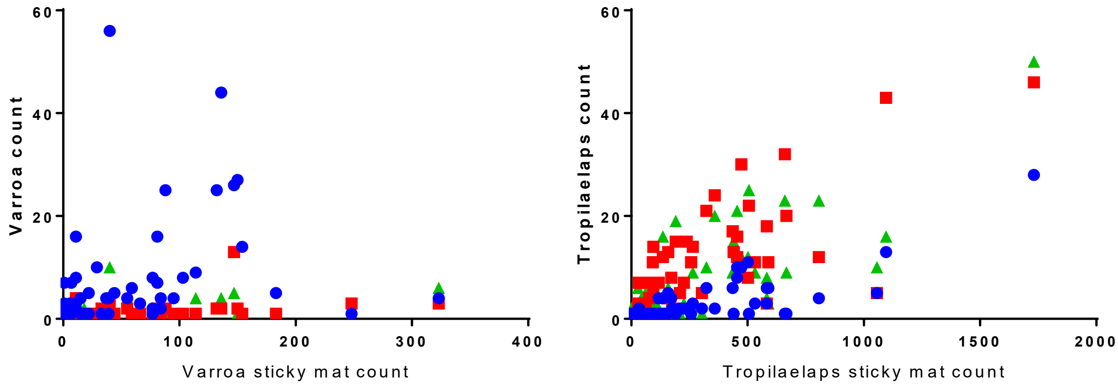


Figure 22: Correlation between mite numbers estimated from the sticky mat and sugar shake (circles), uncapping (square) and bump (triangles) monitoring methods.

Figure 23: Inserting Bayvarol strips into brood chamber

Figure 24: Queen caging on brood frame and placed in the centre of the colony.

Figure 25: Well established colony from an artificial swarm that was made at the same time as the experiment.

Figure 26: Fitting sticky mats with NDAL Honey Bee Extension Officers.

6.3 Developing 'best practice' mite management in PNG

This experiment has provided the first comparative data for different mite management strategies in PNG. This is important for informing PNG beekeepers and giving them confidence to adopt new approaches. The information from this experiment will empower PNG beekeepers and extension officers, with the help of the project team, to develop 'best practice' guidelines to control mite populations under PNG conditions and for different skill levels. The merits and limitations of the tested treatment options and next steps for improving mite management are discussed below.

Bayvarol

Bayvarol® was found very effective, particularly for *V. jacobsoni*, and has the benefits of being a relatively quick and easy method. The main issues relate to cost, health and safety and chemical resistance. Chemicals in hives can pose human health risks via improper handing during application and also via contamination of honey be products. While these chemicals have been tested, certified and deemed safe for use within bee hives, ensuring they are correctly used and handled should be an important component of future honey bee pest and disease education and training programs. Bayvarol® can contaminate honey and so should only be used during the off-season (April – September) when there is no surplus honey in hives to harvest. Reports by NDAL suggest that in order to reduce costs associated with Bayvarol® beekeepers are undertreating and often forget to remove strips after 8 weeks. This has major implications for the sustained use of the chemical by increasing the risk of resistance developing. Realistically, K6.00 for a single Bayvarol® strip (min 24Kina per treatment per production hive) represents a high cost to beekeepers, which they are likely unwilling or unable to pay. Greater understanding of the cost-benefit of chemical treatments such as Bayvarol® will help inform beekeepers decisions.

Queen caging

Queen caging is a non-chemical control method that only requires the purchase of a queen cage at K5.00. Assuming the cage is replaced after 5 years, this equates to a treatment cost of approximately K1.00 annually making this a very affordable option. There is more skill required from beekeepers in being able to find and place queens into the cage to minimise the risk of harming queens during handling or being kept in the cage, although there were no queen losses in this study. An earlier trial by NGF where 100 queens were caged found less than 5% queen loss. The cost of a replacement queen from a breeder can be considerable (K40.00), but teaching beekeepers how to make self-raised queens would reduce the risk of losing queens from caging. These queens can then later be re-queen from breeder stock if required. In this study, the effects of queen caging were limited to *T. mercedesae* and then only for about 2 months. A possible approach for having improving control against both mite species could be a combined treatment with Bayvarol®. By creating a period without brood through queen caging, *Varroa* and *Tropilaelaps* mites are more exposed to the chemical treatment.

Artificial swarm

Making an artificial swarm produces a similar effect to queen caging but does require more skill and upfront costs. A beekeeper will need an additional 8 frame hive box with lid, bottom board and foundation (K188.40). However, the new colony can then be sold a year later for K380.00 at a profit of K191.60. Alternatively, the hive can be kept to increase hive numbers and produce honey for the beekeeper, in which case another 8 frame box (no lid or bottom board) would be required at a cost of K108.00. It could be expected that 21.57Kg could be harvested from this colony worth K280.41. Total initial investment cost would be K296.40 for this double story hive at a loss of K16.00 in the first year. The following year would see a profit of K264.41. If the colony is well managed and there is a good honey season, a beekeeper should be able to repay the investment within a year for double story hive made from an artificial swarm, whilst implementing some mite management within their operations. This method also represents a method for smallholder beekeepers to upscale their enterprises and create alternative income through sales of bee hives. However, the method is dependent on suitable conditions for colony growth and still requires additional integrated mite management strategies.

Conclusion

Ideally, beekeepers should be encouraged to develop an integrated pest management strategy that uses the most appropriate method*s* to suit their circumstances and the field conditions. This may include multiple mite management methods. For example, beekeepers may use Bayvarol® in August before the honey flow and then use a queen caging method before the minor flow in June/ July.

The timing and number of treatments to achieve optimal mite control will need further investigation to provide 'best practice' guidelines for PNG beekeepers in different areas. The seasonal dynamics of the mite populations still needs to be better understood to assist with timing of treatments, which are likely to vary in different provinces. There is also an urgent need for another chemical option of a different chemical class to avoid resistance build-up in mites. Potential options include coumaphos (Check-Mite®) and amitraz (Apivar®) as non-pyrethroid synthetic chemicals, and thymol (Apiguard®) and formic acid (Mite Away® quick strips) as organic chemicals. Further training and extension would be needed to reflect different treatment options and ensure safe handling and correct application.

The productivity and growth of PNG's beekeeping industry requires active integrated mite management protocols, supported by ongoing extension and training for smallholder beekeepers.

6.4 *A. cerana* observations in PNG

Apis cerana colonies were opportunistically sampled during the project activities (Figure 27). Two wild nests were sampled in Goroka, EHP and a third colony sampled in Chuave, Simbu. Brood combs from the EHP colonies were inspected for mites and disease, but only adult bees were able to be collected from the Simbu colony. A total of 902 drone cells were examined with 30 *Varroa jacobsoni* mites found. No *Tropilaelaps* mites were detected in *A. cerana* nests. It is important to note that the *V. jacobsoni* infesting *A. cerana* is not the same as mites now infesting *A. mellifera*. A small number of mites from the *A. cerana* population recently host shifted to *A. mellifera* in PNG, but the remaining mite population is still unable to reproduce on *A. mellifera*. Further, *V. jacobsoni* can only reproduce on the drone brood of *A. cerana*, whereas both worker and drone *A. mellifera* brood are parasitised by the new pathogenic *V. jacobsoni* (Roberts *et al*. 2015).

Several *V. underwoodi* were also found co-invading brood cells. This mite is a known parasite of *A. cerana* in PNG and does not currently present a major risk to *A. mellifera* (Anderson *et al.* 1997). Advanced sacbrood virus was detected in one of the EHP *A. cerana* colonies, with many larvae presenting advanced symptoms of sacbrood disease (Figure 28). The strain of sacbrood virus infecting *A. cerana* is not widely reported to infect *A. mellifera* and has not been found causing disease in *A. mellifera* (Gong et al 2016; Roberts & Anderson 2014).

Figure 27: *Apis cerana* drone brood capping's with characteristic pin hole pores and *A. cerana* worker bees on pollen comb.

6.5 Pathogen screening for EFB and DWV in PNG

The project team tested 10 samples of adult *A. mellifera* from the EHP and the three *A. cerana* colonies against two strains of DWV. Consistent with earlier virus testing in 2015, all samples were negative for DWV. This is important biosecurity information for PNG, as this virus causes significant disease in association with *V. destructor* and *T. mercedesae* around the world. It is highly likely that the impact of *V. jacobsoni* and *T. mercedesae* would be much more severe with the addition of DWV. Therefore, it is important to consider the risks of introducing DWV with any possible future stock importation. Australia has also been recently found not to have DWV (Roberts et al., 2017) and could therefore be a potential source of new genetics. One hive in Lufa district presented with symptoms consistent with advanced EFB infection in May 2018, however 3 field test kits were all negative. In an effort to relieve the stress on the hive, an application of Bayvarol® was given. The cause of the brood disease symptoms remains unknown. Discussions with NDAL apiary officers suggest that these brood disease symptoms have been observed sporadically. We provided NDAL with several EFB and AFB field test kits and encouraged them to test any other colonies they find with similar symptoms.

7 Fiji Honey Value Chain

7.1 Overview of Value Chain Analysis

Each activity involved in the production process of a commodity, right through to final consumption, influences the value of a product. In the 1980's, Michael Porter described this process as the 'value chain'. Value chain analysis (VCA) is a way to visually analyse the flow of a commodity through the process from production to consumption and assists in identifying the various actors in the value chain at each stage in production, their roles and functions, and the vertical and horizontal linkages within the production process. The ultimate goals in performing a VCA is to maximize value creation while also monitoring and minimizing costs in order to create competitive advantage.

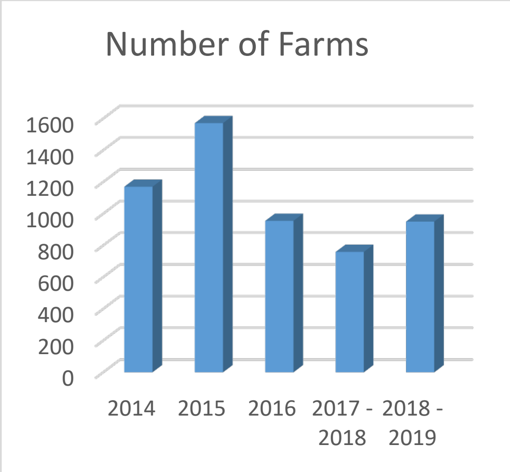
7.2 Profile of Beekeeping Sector

In Fiji, beekeeping is a predominantly male-orientated activity, with the Head of Apiculture for the Ministry of Agriculture Fiji estimating only 5% out of 1,200 beekeepers are women (Asween Kumar, personal communication Feb 2019). Government statistics indicate that there are approximately 950 beekeepers registered, managing 12,000 hives producing one hundred and nine metric tons of honey (Table 8).

Table 8: Number of Farmers, Hives and Production Levels by Location.
Source: Ministry of Agriculture Apiculture Report Q1 2018-2019

Location	*Farmers*	*Hive Numbers*	*Honey Production (Tons)*
Western	478	6448	82.40
Northern	295	4675	14.07
Central	118	538	5.95
Eastern	59	702	6.74
Total	**950**	**12,363**	**109.16**

Interview data, obtained as part of industry consultation, indicates that the 12 larger-scale beekeepers alone produce this quantity of honey and that there are around 805 smaller beekeepers, averaging 7 hives each, producing around 200 metric tons or nearly double the official estimate (Satish Narayan unpublished report to Ministry of Agriculture and Livestock 2018). Official figures indicate average honey production of 22-25kg/hive with up to 40kg/hive achieved on some outer islands. The number of farmers, hives, and production levels were seriously affected by Tropical Cyclone Winston in 2016 (Figure 28). Since then, recovery action has seen levels of participation and production increasing, while not yet reaching pre-TC Winston levels.



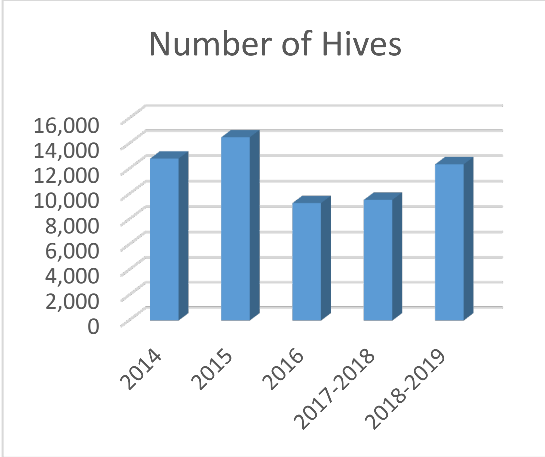


Figure 28: Number of Farms and hives

Source: Ministry of Agriculture Apiculture Report Q1 2018-2019

Discussions with key informants indicated that poor results have been achieved by a number of aid programs, as many smallholders enter the industry without adequate training and support. This observation was confirmed through direct observation and through discussions with smallholders undertaken for this study. Issues include poor understanding of nutrition, which led to overharvesting and inadequate food reserves left for bees to survive the dearth. No understanding of the need to re-queen for youthful vigour or to improve genetics (many beekeepers we met reported that they had not seen a queen). Most could not even do simple 'walkaway' splits to increase hive numbers or replace failed hives. Woodware tended to be untreated and in a poor state[1], bee sites were often established in flood zones[2] or not properly secured during the cyclone season. The president of the Fiji Beekeepers Association, noted that most smallholders do not have: the benefit of traditional agricultural extension; government or NGO-sponsored training; or access to beekeeping books in any language. Business training is also required for beekeepers — basic bookkeeping, cash flow management, planning for equipment replacement, marketing and understanding customers. Our observations were that two levels of training were needed. Firstly, higher level training, including 'train the trainer' skills for staff from Department of Agriculture and Livestock, larger beekeeping operations, NGOs and Biosecurity. Secondly, basic training targeted to new and existing beekeepers.

7.2.1 Major Beekeeping Areas

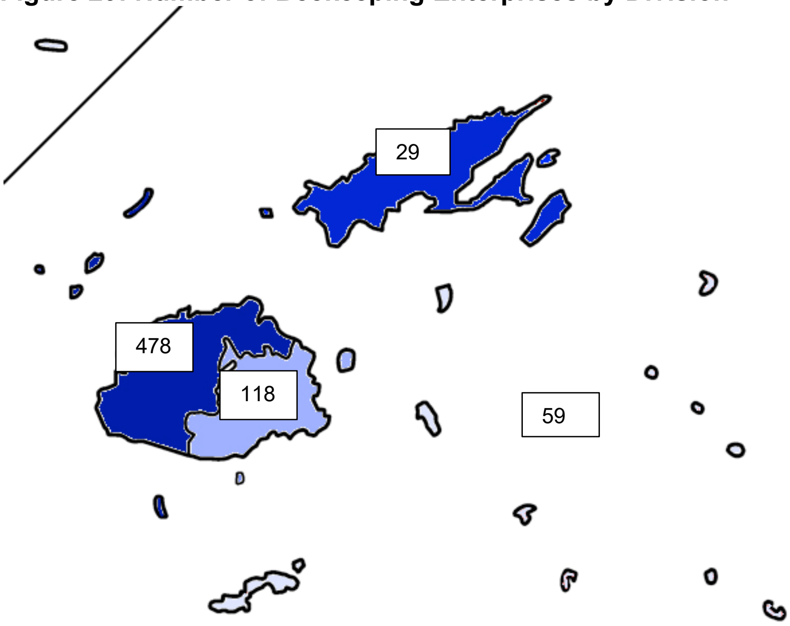
Beekeeping is difficult in wet humid regions and is therefore focused in the drier areas found in the Western Division on Viti Levu and Northern Division of Vanua Levu (Figure 29).

There are two annual harvests or honey flows - one in May-June and the other in November-December. Only a few larger beekeeping operations migrate hives to take advantage of flowering events/nectar flows in different regions. Many reported a lack of access to sites and difficulties in getting permission to access forest sites. Consequently, most beekeeping is stationary and based around the beekeepers' farms or villages. All respondents reported a lack of drones between January and March indicating a dearth in food and few interviewed indicated that they either feed bees or were aware of the need to do so. Many smallholders reported robbing hives during this time of dearth to cover school

[1] It should be noted that the rotting away of beehives after 3-4 years had the advantage of removing a reservoir of pests and disease.
[2] Where land was freely available or uncontested.

costs for children, unaware of consequences and potential for colony collapse due to starvation.

Figure 29: Number of Beekeeping Enterprises by Division



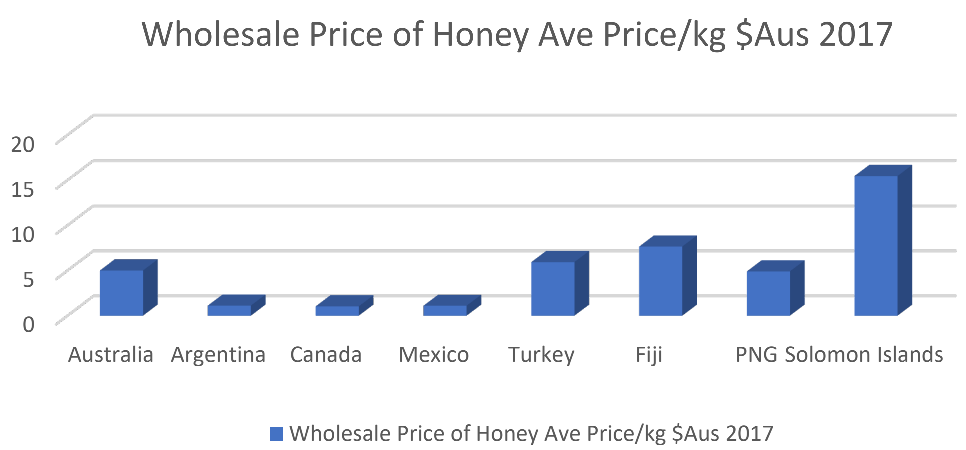
Source: Ministry of Agriculture Apiculture Report Q1 2018-2019

7.2.2 Competitive Advantage of Beekeeping in Fiji

Beekeeping in Fiji is currently underdeveloped and has the potential to provide significant income generation and employment opportunities for beekeepers, input suppliers for the beekeeping process, and through value adding bee products.

The current ban enacted under Biosecurity Authority of Fiji (BAF) in 2013 on honey imports has reduced the supply of honey in the market, and with a continued demand, the domestic price for honey has increased notably. The per kilo price for honey in Fiji is high on an international scale (Figure 30). This has assisted in creating a favourable environment for local honey producers with greater profitability in their operations and lack of cheap international competitors in the market.

Figure 30: International Wholesale Price of Honey



Fijian honey has the quality and marketing potential for export markets, however production levels are currently insufficient to meet local demand. Honey produced has a red colour which is a unique and preferred quality by some consumers. Fijian honey is also organic by default - however this is threatened by the recent outbreak of *Varroa*. These factors combined with the picturesque image of Fiji's tropical islands offers great marketing opportunities for Fijian honey producers, with the potential to demand premium pricing in high value markets. To achieve this, assistance is required in increasing supply, connecting producers to markets, and in the development of successful marketing strategies.

Overseas seasonal employment opportunities exist for skilled Fijian beekeepers in New Zealand and Australia where seasonal shortages of skilled beekeepers exist. Not only would this benefit the hosting countries, but it would also allow the transfer of skills and experience back to Fiji.

7.3 Value Chain Analysis in Fiji - Actors & Functions

The Value Chain Analysis Map can be clustered into the following groups: input supply; production; collection, bulking, processing & packaging; distribution; marketing; end-markets; and support services.

7.3.1 Input Supply

Input suppliers represent organisations involved in the construction and distribution of beekeeping equipment sold to producers. There are three main input suppliers based in Fiji: Commercial Beekeeping Supplies and McKenzie Beelines based on the main island of Viti Levu and Azaad Constructions based in the Northern region of Vanua Levu.

The majority of the equipment supplied to beekeepers is imported. Since 2008 suppliers have benefited from duty free importation on products used for agriculture. Addressing high demand for beekeeping inputs and rising costs of imports, local businesses are manufacturing boxes and frames using local materials and labour. This has brought the prices down for smallholder farmers, although at the cost of quality as local untreated wood used in hive construction is reducing the longevity of the bee box. Additionally, a major obstacle to smallholders building their own bee boxes is the absence of handsaw in villages.

Suppliers noted there is a much greater demand for cheaper inputs over quality materials, with both Commercial Supplies and Azaad Constructions quoting less than 5 percent of beekeepers willing to pay more for higher quality inputs (Satish Narayan, personal communication 2019; Mohammed Sameer, personal communication 2019). This reflects the subsistence nature of beekeeping for the majority of farmers. Cheaper inputs increase accessibility and affordability thus increasing the number of farmers but impact on the longevity of these enterprises. High quality inputs are more necessary for larger-scale producers (i.e. those with 30+ hives).

Suppliers are able to manage normal seasonal demand for inputs, but they report issues in supplying development programs that place significantly large one-off orders at short notice. Issues have been noted in the supply of weak hives, newly purchased hives dying, and in spreading of pest and diseases (*Varroa*). As of February 2019, BAF have enacted a mandatory restriction on the movement of hives and suppliers are now required to get BAF approval before hives can be moved into or between bee yards. Although this is a serious impediment to the industry and to supplier operations, the goal is to stop the spread of pest and diseases.

Key Inputs:

Modern Beehives (Langstroth Hives): these types of hives are either imported or manufactured by carpenters. The total cost of a single-story hive, including fames and bees in Fiji is $475FJ (Table 9).

There are some beehive suppliers in Fiji, such as Commercial Honey Supplies, that import and assemble components, and numerous carpenters who are contracted from time to time to manufacture beehives on behalf of beekeepers. Some operations were using corflute nucleus hives attracted by lower weight and cost considerations ($5FJ per unit purchased in lots of 1200).

Bait Hives: to attract bees, beeswax or propolis is used but sometimes sugar syrup or honey may be used as bait. Sugar is locally manufactured in Fiji and is bought from local shops, although white sugar is reportedly not available in bulk. There were few reports on the use of swarm traps during conversations with key informants.

Bee (Harvesting) Suits/ Veils: this clothing includes a veil, gloves, boots and an overall that are used to protect the beekeeper from being stung by bees. The protective clothing is imported and price of the whole set ranges from $110FJ. Despite Fiji's history in textile production we found no local manufacture of protective bee clothing across the country and found no materials for making them in stock.

Smokers: are used to calm the bees during hive inspections and harvest. They are imported and cost between $50FJ each.

Buckets: to store honey during harvesting and transportation to the markets or collection points. Most beekeepers use 15-20 litre size plastic buckets, which are imported (or reused from other purposes such as cooking oil, syrup or biscuit tins). Commercial beekeepers do not use bulk storage containers as neither they, nor the wholesalers they are supplying, have the capacity to load and offload them onto trucks. Instead commercial beekeepers use larger 30kg drums and manually load and off load.

Although these are the standard inputs required for beekeeping, many beekeepers in Fiji and PNG are unable to access modern bee hives and equipment particularly harvesting suits, smokers and mechanical extractors (unless supplied by government or NGOs) due to lack of access to loans. In fact, all the various NGOs that are working with beekeepers provide the equipment – others for free and others on loan but the results of those who provided on loan have been disappointing. It should be noted, and discussed further that beekeeping loans in Fiji have, reportedly the highest failure rate of all agribusinesses.

Table 9: Price of beekeeping inputs

	PNG		Fiji	
Item	**PGK**	**AUD**	**FJD**	**AUD**
Box Local	57	23	100[3]	65
box imported	87	36	48	31
Nucs (bees)	200	81	300	192
Frame	3.5	1.4	5	3.2
wax	5.9	2.4	1.5	1
lid (local)	40	16.2	30	19
bottom board(local)	35	14.12	25	16
split board (local)	30	12	-	-

[3] *This includes 10 wired frames*

bayvrol strips	7	2.9	n.a.	n.a.
overalls	300	122	-	-
Boots	-	-	41	26
Smoker	260	105	50	32
Hive Tool	85	35	29	19
Veil/jacket	106	43	110	71
single beehive with bees	400	176	475	303

7.3.2 Finance/Grants available in Fiji

This section of the value chain describes financial services available to beekeepers to start and expand their operations.

Fiji Development Bank (FDB)
The FDB provide financal assistance in the form of loans to enterprises. The bulk of their portfolio comes from agricultural loans (51%) (FDB Annual Report 2015). Challenges arise in the technical knowledge needed to be able to report accurately on agricultural production, and particularly in forecasting income. This is especially evident in honey production due to its highly technical nature which greatly influences the success or failure of each beekeeping enterprise. As such, FDB rely on the Ministry of Agriculture (MAF) for technical support.

Northern Development Program (NDP)
The aim of the NDP is to foster the start-up and growth of micro, small and medium enterprises (MSMEs) through equity assistance in the form of a grant. NDP operates in the Northern Division as it is more rural and less developed than other regions. NDP provide a grant component if the applicant gets approved a loan by FDB. This grant/loan combination mitigates risks in lending to those considered risky clients, it increases the pool of funds available for the applicant while reducing the subsequent debt burden. NDP face challenges in regard to technical knowledge for accurate reports on beekeeping operations and thus rely on MAF for support.

Integrated Human Resource Development Program (IHRDP)
The goal of IHRDP is to develop programs which foster employment and income generation for disadvantaged communities. They provide grants in the form of equipment to village groups. Following TC Winston, IHRDP provided 59 villages with 20 double story hives in Vanua Levu. Major challenges have arisen in training and skill development, hive management, pest and diseases, and monitoring of these projects. As a result, many hives have died and been left to rot. IHRDP rely heavily on MAF for technical assistance and training and extension. The organisation requires guidance on how to best implement community beekeeping programs and support in regard to technical beekeeping information as well as training and capacity building for the villages.

Ministry of Industry Trade and Tourism (MITT)
The MITT provide grants to start or expand micro and small businesses for lower income households. The $1,000 grant is paid directly to suppliers. There are no training requirements for farmers to receive these funds and as a result, there is a sizable number of beekeepers with no training or technical skill who own 2-3 hives. Challenges have arisen with unreal expectations in management of hives, access to other beekeeping equipment (centrifuge), and overdependence on MAF for support.

7.3.3 Production

This section of the value chain comprises the primary producers of honey. Producers are categorised into four groups, subsistence farmers, semi-commercial farmers, commercial farmers, and community projects. The categorical definitions for producers are in line with the Fijian Ministry of Agriculture definitions at 1-40 hives for subsistence, 41-75 hives for semi-commercial and 76+ for commercial enterprises.

Subsistence farmers comprise the majority of honey producers, holding 51% of the country's total hives (Ministry of Agriculture 2019). Subsistence farmers sell to the local market, bulking agents and cooperatives. During focus group discussion, farmers emphasized the need for training and skill development to increase production. In a survey of farmers from the Northern Division, 43% of respondents had not received any training. When asked what farmers required to increase production 62% of respondents listed inputs (more boxes or hives, extractor/tools, and finance) and a further 19% listed more knowledge and skills. Some of the biggest challenges faced by farmers were access to inputs and finance, transportation, management and maintenance of hives and the weather.

Semi-commercial and commercial farmers sell their honey to bulking agents, cooperative societies or direct to retailers, packaged and branded. Commercial producers face challenges with capacity and development in expansion, with little mentorship and guidance, and limited large-scale companies in-country to benchmark and learn from.

Community-owned projects have been used as a tool for development through employment and income generation for rural villages, particularly in the Northern Division. Fiji Agromarketing collect the honey directly from the villages. The skills and technical capacity for the villages is lacking, as well as access to training and support services. As a result, production levels from these projects have decreased markedly.

During focus group discussions, a common issue raised was the lack of market for farmers to sell their honey. Middlemen are seen as unreliable by some farmers as they reported they often changed the price without notice. Bulking agents and cooperatives are seen to offer too low a price. Farmers emphasized the need to source their own market to get a good price for their honey.

Surveys conducted in the Northern Division revealed the price paid for honey ranges from $10-30/kg with a mean of $16.75. Middlemen in the village pay $10-12/kg who then bottle it and sell in the produce markets for $25/kg. Prices for some key bulking agents and cooperative societies are listed in Table 10.

Table 10: Wholesale Price for Honey

Organisation	***Price***
Fiji Agromarketing	$13/kg (was $11 prior to 12/02/19)
Central Bee Keepers Association (CBK)	$15/kg
Northern Beekeepers Association (NBA)	$20.83/kg (converted from $30/L)
Nahls Pure Honey	$10-12/kg

7.3.4 Collection, Bulking, Processing, & Packaging

This stage through the value chain is critical in enabling honey to get from the farm to the necessary markets, and at the quantity required. The main collectors, bulking agents, processors and packagers include:

- Traders who sell at local produce markets
- Private sector companies who sell under a unified brand name
- Cooperative societies
- Government organisations

The high demand for honey year-round paired with the bi-annual honey flow and lack of honey produced during the rainy season, creates challenges for bulking agents. Producers want to sell their honey immediately after harvest, requiring bulking agents to purchase and hold inventory. This can be hampered by cash flow management and purchasing capacity of these enterprises.

Cooperative societies offer a competitive price for farmers to sell their honey. They also face challenges in supply as production levels are unable to meet the demand.

Fiji Agromarketing are a government organisation who purchase honey wholesale from the farm gate for the Northern Division whose market hasn't yet been served by the private sector. They process and package it for sale in a small number of minimarkets around Suva and to hotels and resorts. Their biggest challenge is securing enough supply to meet their orders. Forecasted demand is 1tonne/month, however some months they can only secure enough to meet 20-50% of these orders, with some orders put on hold for up to two weeks.

7.3.5 Distribution

This section of the value chain provides the link to consumers and comprises the local market stalls, retailers and hotels. Through these channels honey is distributed widely throughout Fiji. The main retailers are minimarkets and supermarkets, particularly Max Valu-U, IGA, Ram Jattan Supermarket, and RB Patel Supermarket.

7.3.6 Marketing

The marketing strategy of different bulking agents influences the real and perceived value of honey, as well as the price.

Placement in the market has partly influenced the price, with higher prices observed closer to the capital city Suva and lowest prices in the Labasa produce markets. Honey sold in pharmacies and airport stores benefit from premium prices. In the local produce markets of Suva and Labasa, the average price for honey was $25-31/kg and $20-23/kg respectively. Honey was of consistent colour from different stalls and all sold in recycled plastic bottles. In the supermarkets, honey brands observed were predominantly from commercial suppliers and bulking agents. Prices range from $25-35/kg depending on size and brand. In minimarkets, honey was from commercial suppliers, bulking agents, or local producers. Prices range from $21-27/kg depending on size and brand. The honey observed in pharmacies in Suva charged a higher price at $32/kg. The same brand observed in a supermarket in Nausori was priced at $26-28/kg, indicating the medicinal value of honey is worth a premium price to consumers.

Cooperative brand honey was not observed in any supermarkets or minimarkets and Fiji Agromarketing's presence was minimal (only seen in two minimarts).

There is little influence of different quality products on price. Organic honey sold in the Nadi airport charged a substantial premium (although has different target market), however with retail honey, it is mainly dependent on consumer preferences with some preferring red over the gold honey, and vice versa. There are limited quality issues at present, however there is little evidence of testing for sugar syrup adulteration.

There were few differences in packaging between commercial suppliers/bulking agents with honey sold in plastic bottles with basic labelling. Only two brands observed had a squeeze lid. No honey was observed in glass jars.

The development of greater marketing strategies for bulking agents and commercial producers can offer significant benefits in reaching higher value markets and enabling premium prices.

7.3.7 End Markets for Honey

The main market for packaged honey is the domestic consumer market who use honey as a table food product. Nearly all of the honey produced within Fiji is consumed locally. The per capita consumption of honey in Fiji is either 220 grams or 440 grams per year (depending on which production figures are accepted) compared to 800-900 grams per capita in Europe and 4 grams of purchased honey per capita in PNG. Recently, reports of artificial/adulterated honey sales have emerged which has the potential to cause reduced domestic sales due to price competition or lack of consumer confidence in local honey quality (fear of adulteration). While honey imports into Fiji are banned, government officials are investigating possible breaches in recent times.

Honey was observed in small 45-85g medicinal bottles in supermarkets, minimarkets and pharmacies. These small quantities are primarily used for cultural purposes as part of Hindu offerings or alternatively for medical purposes (i.e. wound dressing). The per kilo price is much higher at $39-55, however this is a small niche market.

7.3.8 Support Actors & Functions in the Honey Industry

Government Support

National Government agencies that provide support to the honey industry include: The Ministry of Agriculture; Biosecurity Authority of Fiji; Ministry of Industry, Trade & Tourism; Ministry of Strategic Planning, National Development & Statistics; and, Ministry of Social Welfare, Women & Poverty Alleviation.

The Ministry of Agriculture (MAF) maintains two small honeybee research centres — one at Batiri and the other at Dobuilevu. While intended to support queen breeding and colony improvement, in recent times these centres have focused on the provision of nucleus colonies to beekeeping development programs dealing with the aftermath of Tropical Cyclone Winston (2016). Currently there is little genetic selection occurring as neither beekeepers, nor the queen breeding centres, appear to be systematically selecting for desirable traits and have a limited understanding of queen breeding programs and techniques, apart from a preference for yellow over dark bees (believing a correlation exists between the genetics for aggression and colour).

The MAF are responsible for education and extension services to beekeepers, as well as national production levels. All MAF extension officers have had training to provide beekeeping assistance to farmers, however extension officers are usually responsible for up to seven other agriculture commodities, have limited beekeeping skills, and are unable to provide the technical support needed for beekeepers. The majority of enquiries are then sent to the head of Apiculture. The Apiculture department provide demand-based free training to farmers covering basic beekeeping skills, construction of inputs, queen breeding, and bee pest and diseases. As well as supporting individual farmers, other organisations that rely on technical support from the MAF include FDB, NDP, and IHRDP. MAF in some cases are asked to essentially manage ‘hand out’ hives from development programs and try to give training while they are on site. The capacity for MAF to attend to all the dependent parties is limited, and further stretched with the implementation of new development programs and grants that have begun without consultation and collaboration.

The *Biosecurity Promulgation Act 2008* provides for honey import controls, border quarantine and inspection, ongoing field surveillance, and the ability and willingness to respond to serious outbreaks of pests and diseases. The Fijian Beekeepers Association report an excellent relationship with the Biosecurity Authority of Fiji and have worked closely with them on management of AFB programs. Commercial shipments of honey do not receive import permits and illegal imports are destroyed although, up to 20kg of honey can be imported into Fiji for personal use without heat treatment for control of the honeybee diseases EFB and chalkbrood. Sugar syrups have been reportedly imported and mixed with honey to form an adulterated product that would not comply with the international food standards ‘*Codex Alimentarius’.*

Cooperatives

Cooperatives offer support through training and educational materials, technical assistance, and community forums. The Fiji Beekeepers Association (FBA) provides beekeeping information and training in order to improve skill levels of beekeepers, conducts innovative mentorship programs to connect less experienced beekeepers with experienced mentors and has been particularly successful in encouraging women into beekeeping. Most technical skills and knowledge stem from FBA, is filtered through regional cooperatives, and down to the farm level.

FBA work closely with divisional cooperatives, including Northern Beekeepers Association (NBA), Central Bee Keepers (CBK), and Ba Rural Beekeepers Association. These divisions assist in the dissemination of information to the farm level, provision of training and education materials, and in providing a market for farmers to sell their honey. The strong link between the farmers and cooperatives facilitates communication not only within the industry, but also between FBA and government bodies (MAF, BAF).

7.4 The Value Chain Map in Fiji

The following valuer chain map indicates the main actors along the honey value chain (Figure 31).

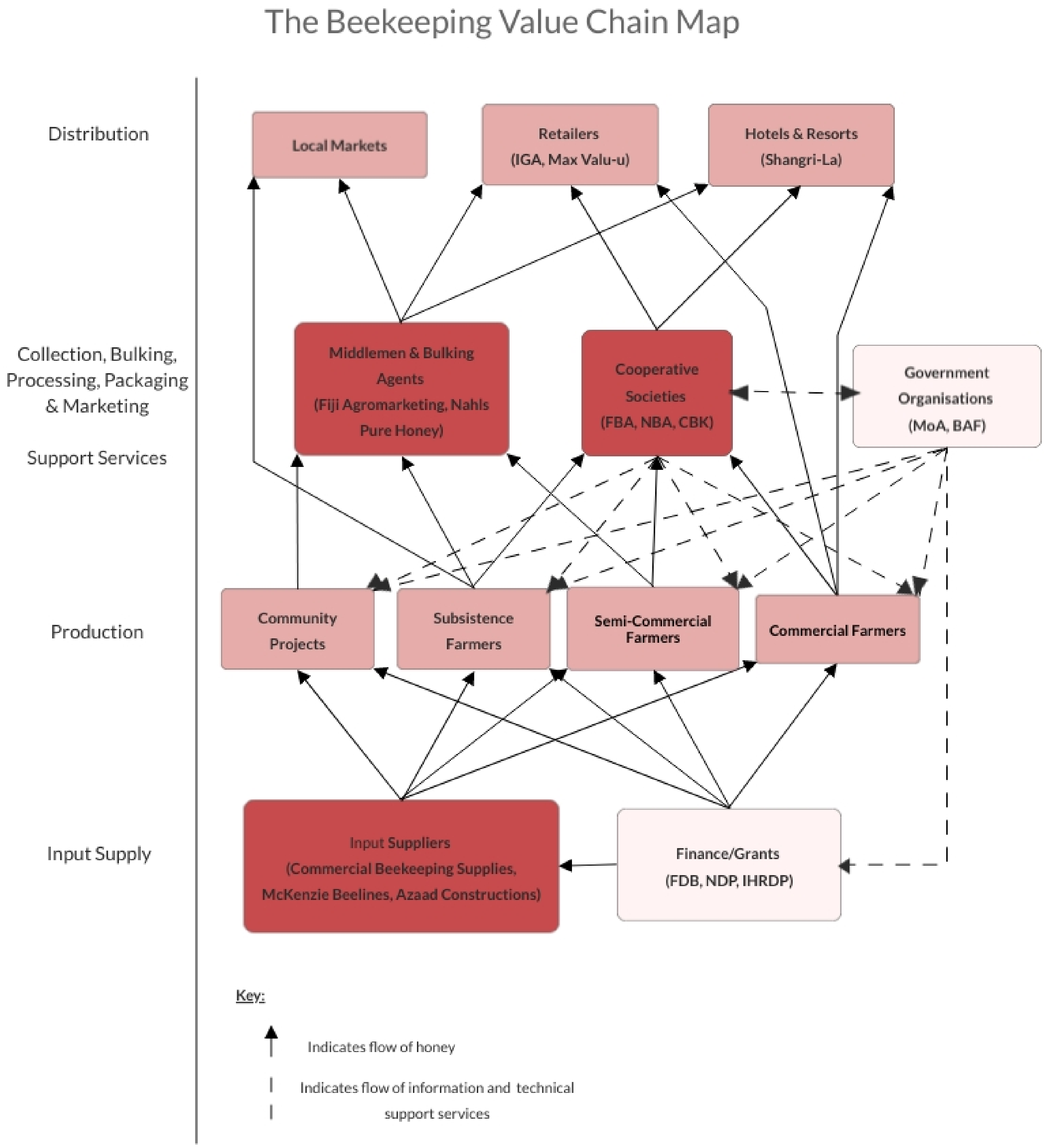


Figure 31: Fijian Honey Value Chain Map.

7.5 Analysis of the Value Chain in Fiji

The main considerations to overcome in the honey VC include:

- Farmers should treat beekeeping as a business by investing in a minimum of 10 beehives each;
- Cooperatives need a strong governance structure and beekeepers need a good understanding of their roles and rewards and an ability to price honey correctly;
- Provision and support of beekeeping equipment and group storage facilities to beekeepers and assisting small-scale processors should be linked to financial service providers so that they access funds as working capital and invest in capital equipment for processing (only after intense training);
- Access to finance remains a key challenge to beekeepers and small-scale processors who are the primary players in the chain. An understanding of basic beekeeping is required to help ensure those receiving finance are able to service the debt.;
- There needs to be strong linkages established across the VC and amongst the various players; and
- Critical to the success of the value chain is that industry stakeholders or the private sector should have a buy in and drive the process.

Increasing the skills and technical knowledge of farmers should be a key priority in increasing the productivity and profitability of the Fijian honey industry. There is a significant number of untrained beekeepers who not only could benefit their livelihoods through a deeper knowledge and understanding of beekeeping but would also be less dependent on MAF for support, and less likely to exacerbate current pest and disease issues.

Assistance is required to improve community beekeeping programs, in particular training and mentorship programs should be executed to increase skills, cooperative models should be analysed to find applicable strategies, and strategies to encourage genuine engagement from communities should be identified and implemented.

Training the trainers should be a key component for stimulating industry growth. Current training programs have been inadequate in creating sustainable enterprises, with many “trained” beekeepers unable to perform routine tasks. Increasing the quality of training provided facilitates skill development for beekeepers who are then able to grow their current enterprises and in doing so, increase their production and profitability.

Increasing the capacity of apiculture staff within the MAF to support farmers and other relevant stakeholders is necessary for the industry to grow.

Currently, the wax market remains untapped despite great potential for increased profits for actors at various stages in the value chain. In a survey of honey producers, 85.7% of respondents do not sell any other bee-related products. Utilizing beeswax enables income to be generated by what is currently seen as a waste product. Beeswax has great potential in creating value-products such as candles, soaps, balms and others, in creating lower cost inputs (wax foundation), and is a highly demanded product in global markets. As such, building capacity for institutions to process wax and produce value-added products should be highlighted.

The current BAF strategy to eradicate *Varroa* should be analysed for feasibility and impacts on the industry should be measured. BAF restriction of movement of bees and hives creating a serious impediment to the industry.

8 Investigation of opportunities for improving women's engagement in beekeeping in PNG, Solomon Islands and Fiji.

Preliminary findings suggest there is much potential for improving beekeeping capacity for women and youth in supporting inclusion and diversification among small family beekeeping businesses. Beekeeping was reported to be an important income generating activity in the gardens of many rural people in PNG, Solomon Islands and Fiji. The fact that hives can be placed close to the house was considered to be an important aspect to the desired uptake among women's groups in all three countries.

Focus group discussions in collaboration with Oxfam partners, in Gender and Livelihoods, identified that there were no perceived traditional or cultural taboos that would forbid the involvement of women in beekeeping in the Pacific (Figure 36: Figure 37). The SRA also found that there were numerous positive attributes identified which should support women's engagement, particularly when treated as a 'family enterprise'.

Preliminary inquiry suggests that limited exposure to beekeeping and limited access to protective equipment to prevent and reduce the fear of being stung is a concern among women. These are major factors contributing to the present low level of involvement of women in beekeeping. Another major concern raised was the need for training and extension support that was more inclusive at the household level.

Women participating in beekeeping were identified as falling into three main categories: those that work as independent beekeepers; those that work beehives alongside male family members, most commonly their husband; and those engaged in value adding through bottling and selling at roadside or markets etc.

In PNG beekeeping has been adopted by women in a number of provinces including Bulolo in Morobe (south of Lae) and has resulted in the formation of women's beekeeping clubs such as the Bulolo Honey Mamas Association (Kens 2010). In the Goroka District of the Eastern Highlands the members of the Garalupaloka Women's Farmer Group in the village of Gepahina have completed training and established their own honeybee hives (Spore Magazine April 2007). On Bougainville, the female owner of Sankamap Honey Limited had grown her business from ten hives in 2005 to 80 hives in 2011 and was providing employment opportunities for other women (Askin et al. 2011).

Focus Group Discussions were held with 30 women from the Eastern Highlands Mummas Safehouse with facilitation from Sonia Galwi (Safe House Manager) and Marinta Ove (Oxfam, Gender Justice). Women talked about limited economic income generating opportunities and limited income security as they have been forced from homes and are unskilled in an urban setting. 1600 women registered across 8 districts in the Eastern Highlands Province (EHP). Talked about the possibility of making beekeeping inputs and value adding into beekeeping value chain.

In PNG, 119 male beekeepers were asked to discuss the roles and involvement of their partners in beekeeping enterprises. Of the surveyed respondents, 62% indicated that their wife currently helps with general beekeeping activities compared to 30% who indicated their wife does not help (Figure 32). Of respondents that indicated their wife does not help with beekeeping activities, fear of stings (20%) and limited interest (10%) were perceived by males as key reasons for their wives not participating in the family beekeeping enterprise. The combination of beekeeping, harvesting and post-harvesting were the most common beekeeping tasks, participated in by women, with only 8 respondents, indicating their wife takes part in all these activities.

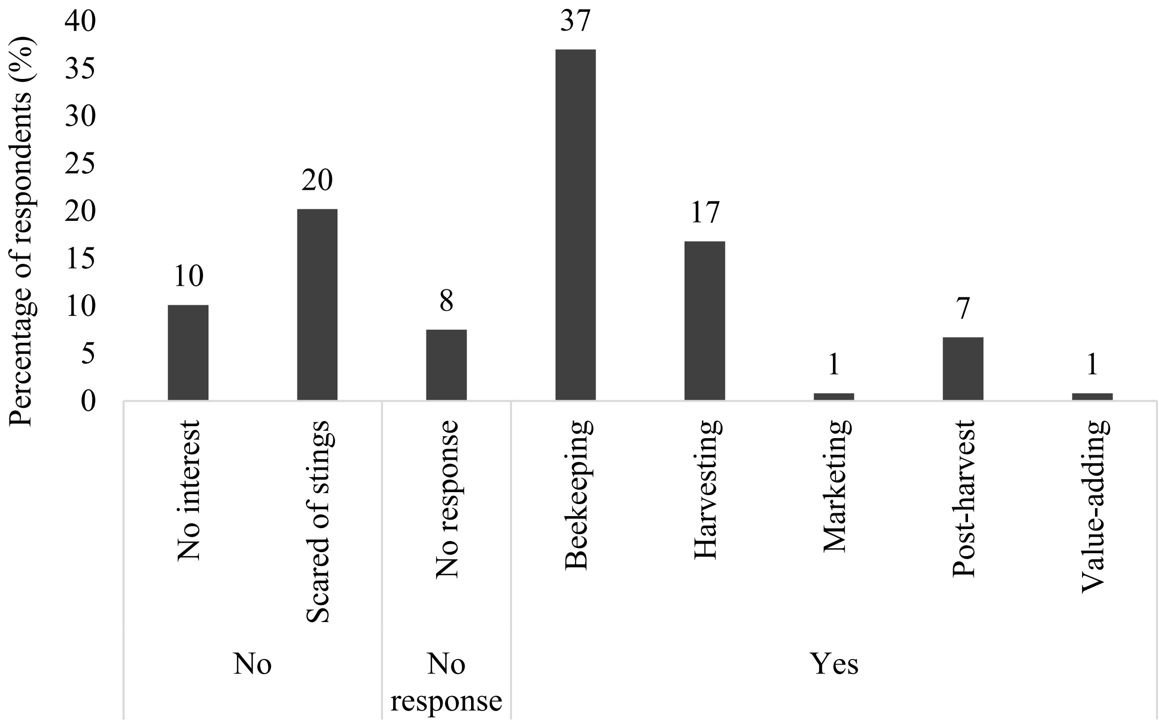


Figure 32:The role of the wife in the family beekeeping business in the EHP (n=119).

The majority of female beekeepers in the EHP work alongside their partner to conduct beekeeping activities. This is consistent with the literature that suggests beekeeping tasks are often shared within the family unit (Pocol & McDonough, 2015). Although this aspect of beekeeping in PNG is similar to other countries, the role of women within family beekeeping operations is somewhat different. The survey data indicates that women in the EHP play a larger role in general beekeeping, while in other countries, women are most likely to participate in post-harvest activities including marketing and value-adding. These post-harvesting activities also offer opportunities for women who are fearful of stings as they don't require direct contact with the bee colony (Ejigu et al, 2007).

8.1 Women's desire for more beekeeping involvement

In total, 26 female beekeepers were involved in discussion in regard to beekeeping. Of respondents, 100% desired more beekeeping involvement. Marketing and selling were areas where women indicated they would most like to have greater involvement (62%) (Figure 33). While 0% indicated a desire to participate in value-adding activities (i.e. making candles and soaps), it is believed this question was not effectively conveyed and further research is needed to verify this finding as this may represent a lack of knowledge about value-adding amongst beekeepers in the EHP and/or concern that the market is limited for local value-added bee products.

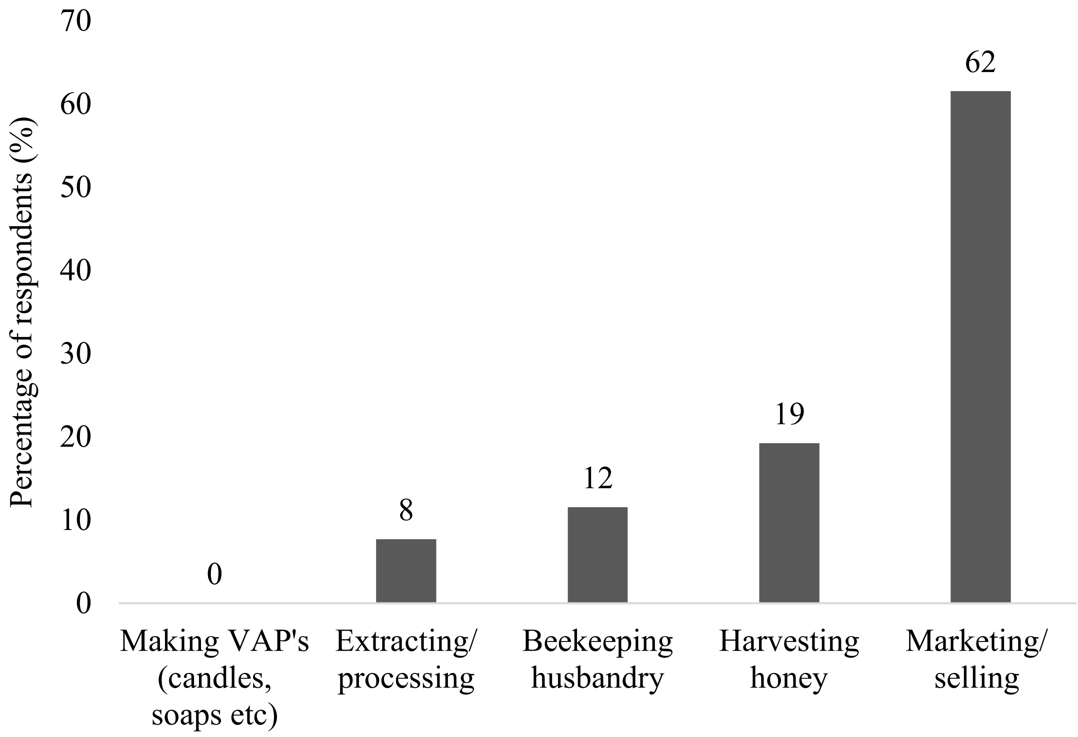


Figure 33: Beekeeping activities in which women desire more involvement (n=26).
*****(n.b. we believe that the concept of value adding of bee products was not clearly conveyed and key informants believe there is greater interest than what is presented).

Marketing and selling of hive products are important aspects of diversification within any beekeeping business. Access to appropriate markets and the knowledge of how to interact with those markets is essential in ensuring income-generation from harvestable hive products. Bottling and labelling of honey can provide local beekeepers with the opportunity to access a direct consumer market and generate more income than from selling raw honey in bulk (Aguiree & Pasteur, 1998). Due to the nature of subsistence food production in the EHP, selling honey or other hive products at local market level may integrate well with existing marketing and sales of agricultural produce and handicraft goods. Marketing and selling hive products don't require direct contact with the hive. This negates the threat of stings identified as a limitation to some women participating in beekeeping in the EHP. A similar beekeeping activity that generates and diversifies beekeeping income without direct hive contact is making value-added products (Hilmi et al, 2011). Further research is required to determine the attitudes surrounding value-added products, what products would be suitable for the local markets and how to provide suitable training to both men and women who wish to diversify their family income from beekeeping activities.

8.2 The location suitability of beekeeping activities for women

In total, 96% of female beekeepers felt that beekeeping can be conducted in a suitable location for women (Figure 34).

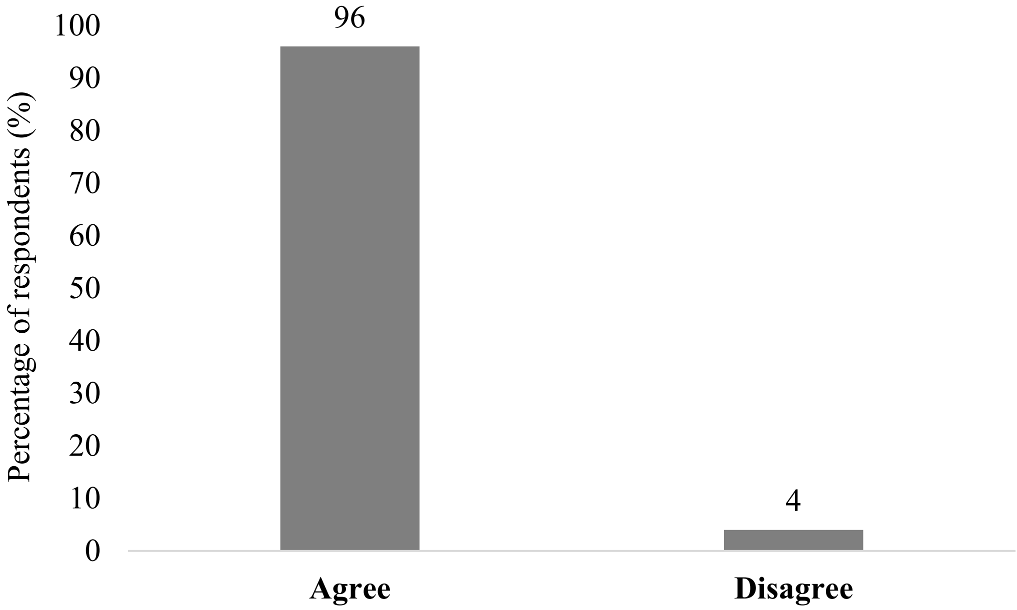


Figure 34: The location suitability of beekeeping activities for women (n=25).

Most women surveyed agreed that the location of beekeeping activities is suitable for women. The background literature supports this finding, suggesting beekeeping can be an appropriate activity for women as it can be conducted close to the homestead, and in conjunction with other work around the home (Bradbear, 2009). This allows women to contribute to household income and develop new skills without disrupting household activities. Income generation close to the homestead has important relevance for women in the EHP, where access to roads and adequate transport is poor and levels of violence against women are high (Asian Development Bank, 2016; Gibson & Rozelle, 2003). For these reasons it is important to note that agricultural extension at the village level also mitigates some of the limitations facing rural women in PNG (Cahn & Liu, 2008). By enhancing training programs at village level as opposed to district level, women are more likely to participate and benefit from the extension programs provided.

8.3 Time suitability of beekeeping for women

Of the women surveyed, 79% agree that beekeeping is suitable to women's time priorities (Figure 35).

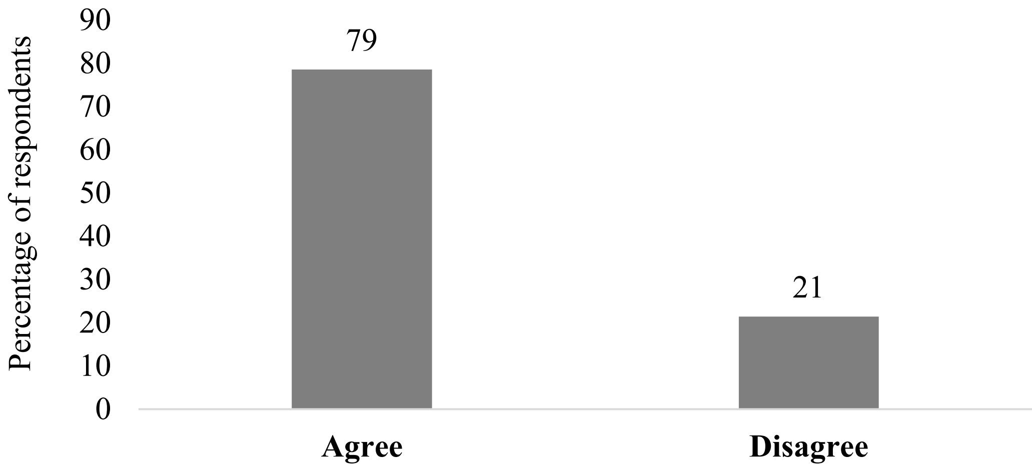


Figure 35: The time suitability of beekeeping activities for women (n=14).

Beekeeping has been previously identified as an activity that suits women's household work as it can be conducted close to the home, with minimal time investment, compared to other more laborious agricultural activities such as coffee production (Hilmi et al, 2011; Pocol & McDonough, 2015). The findings from this SRA provide a vital insight into the limitations to women's participation in the apiary industry in the EHP, however the proportion of overall responses from women was low. Further research specific to women is required to fully understand the complex social, economic, environmental and cultural limitations inhibiting women from participating in cash-income generating activities, such as beekeeping, in the EHP.

Figure 36: Focus Group Discussions with EHP Mammas Safehouse.

Figure 37: Miss Atovo from Benna District, EHP harvesting honey frames.

In the Solomon Islands the Gizo women in business group provided valuable contextual insight into the situation for women in beekeeping and post harvest handling. Focus group discussions and interviews with key informants with these groups were conducted to identify limitations to women's inclusion and to identify solutions to empowering women by addressing identified barriers.

In Fiji, Asween Kumar (Ministry of Agriculture) estimates that less than five percent of beekeepers are women (A Kumar, personal communication, Feb 2019). However, there appears to be a keen interest as women comprised over 50% of those attending introductory training sessions and seminars conducted as part of this SRA. Increasing attention on the potential for beekeeping to provide improved livelihoods in Fiji has resulted in a number of government and non-government organisations providing various groups, including youth and women's groups, with hives and beekeeping equipment. However, some programs have been unsuccessful due to limited attention and access to training. This was highlighted during interviews with IHRDP employees; for example, one women's group in Macuata had been provided with hives and equipment, yet due to isolation, they did not have access to training provided by the Ministry of Agriculture. Without the necessary training, the women reported being frightened to harvest the hives and thus could not sell the honey nor make an income from it. Vilisi Rokotunidau (Central Bee Keepers) also highlighted the language barrier affecting the effectiveness of training, as training is provided predominantly in English. As such, she noted women's and youth groups requesting training in the local iTaukei language.

In contrast, a successful example of a women's group supported by the IHRDP is Tosovata Women's Group. One of the significant influences on their success stems from a mentorship training program through the Northern Beekeepers Association (NBA). The mentor makes regular visits to provide the training and mentorship needed to generate the necessary skills and understanding of beekeeping complexities. In return, the mentor receives a four-frame nucleus each visit. Currently, the group sells honey and nucleus colonies, although they have indicated their interest in making value-added products utilising beeswax. The funds from their beekeeping activities go towards supporting the needs of the women in the group and the education of their children (Figure 38).

These contrasting outcomes highlight the need to facilitate inclusive, accessible and effective training programs targeted towards women's engagement, both within households and for women's groups, through which greater livelihood outcomes can be sought. Furthermore, this highlights the need to further develop family farms team approaches within beekeeping training and investigate the causes of neglect from aid-provided hives, so to identify strategies to improve the successful uptake of these programs and their contribution to improved livelihood outcomes.

The promotion and empowerment of women and families to be successful beekeepers and diversify incomes from honey bee products is an important focus for the partners of LS/2014/042. 'Champion' female beekeepers and queen breeders have been identified in both countries and in country community, gender and household development professionals have been identified through the SRA to help facilitate this shared objective. In particular Women's groups indicated a keen interest to value add to bee products, such as beeswax to make candles (particularly citronella candles to keep mosquitos out and away from infants and provide nice scent to households). It was believed making of such products may be of less interest to the male partners.

Figure 38: Miss Lewa Sucutolu beekeeping in Labasa, Fiji.

9 Key issues and recommendations

The following strategies (Table 11) (was collaboratively developed, with key stakeholders, to meet this project's objectives and has formed the basis of the full research proposal (LS/2014/042):

Objective 1: Develop and test appropriate technical, business and marketing practices for new and established bee-based businesses.

Table 11: Proposed activity and outputs

Activity	Method	Output and Milestone.	Risks / Assumptions	Applications of outputs/ Scale
1.1 Assess and review the suitability/productivity of current beekeeping practices in each country.	Inception meetings. Prepare a technical review report for each country Conduct household beekeeping livelihood surveys and field assessments with 100 beekeepers in PNG and Fiji. This will be conducted in collaboration with partners and local institutions to capture farmers current practices, limitations and perspectives on beekeeping in comparison to other income generation streams. Surveys will include specific questions evaluating gendered labour inputs, return on investment, livelihood capital assets, the vulnerability context (trends, shocks, seasonality), transforming structures and processes and livelihood outcomes and other livelihood strategies.	Technical review report for each country Baseline household study. This will evaluate current practices to allow for measurement of effectiveness on interventions at the end of the project and comparative return on investment and livelihood strategies. December 2019.	Incorrect information provided or lack of access to reports. Unwillingness to participate in surveys due to time commitments	Critical information to guide and optimise activities of the project. Report will identify the major issues of beekeeping in regard to technology, nutrition, genetic stock, pests and disease, extension and development. Report used to identify feasibility of beekeeping in comparison to other income avenues in order to inform up scaling capacity of family beekeeping enterprises. Surveys will be conducted on approximately 100 households in PNG and in Fiji

1.2 Review effectiveness of current strategies for starting up small-scale beekeeping projects to identify their level of long-term success/resilience.	Key stakeholder meetings and interviews. Where possible access quantitative data on small scale projects in each country. Interviews with financial agencies and loan providers will be conducted in conjunction with household surveys that incorporate questions relating to loans and finance for beekeeping.	Review report for each country identifying the level of success or failure of start-up strategies such as the use of: loans; cooperatives; and donation of equipment. Specifically 1) develop a case study based on the supply of beehives and finance to rural communities after Cyclone Winston. The Northern Development Corporation on Vanua Levu, Fiji have offered access to their clients to support this study. And 2) Identify strategies to maximise Return on Investment, and include specific questions evaluating gendered labour inputs and compare livelihood strategies in PNG and Fiji.	Incorrect information provided or lack of access to relevant reports.	Information from the review will be provided to key partner organisations and funding agencies to guide best practice for starting up and scaling out of small scale beekeeping enterprises
1.3 Develop a program of improved genetic stock and an understanding of queen-breeding systems to increase supply of queen bees and nucleus colonies to new and existing beekeeping operations.	Engage local 10 queen breeders in PNG and Fiji to develop and deliver training and field days for smallholder beekeepers that promote participatory approaches to self-evaluating and monitoring queen breeding and genetic selection programs according to local conditions. Surveys will be conducted with queen breeders (5 in PNG and 5 in Fiji) on their opportunities and constrains to producing quality queen bees.	Training in queen breeding and genetic selection delivered through publications, workshops and field days. These will be conducted in conjunction with queen breeders involved in surveys and operations evaluation. Follow up surveys will re evaluate changes in capacity to produce queen bees and also their quality using measurable criteria given in training workshops (honey production, docility, swarming tendencies etc.) [4] It is envisaged that 30 participants (from selected beekeepers and extension staff) in both PNG and Fiji would be trained.	Monitoring and evaluation of stock is not continued in the long term.	Improved access to more queen bees of a higher quality and nucleolus colonies for queen breeders and beekeepers. This will be scaled out through existing networks of beekeeping associations and district beekeeping clubs.

[4] Topics will cover all aspects of queen breeding and have practical applications for improving genetic stock, including queen cell production and raising techniques, grafting, nutrition for breeding, breeding stock evaluation and maintenance, selective breeding programs, drone mother colony management, nucleus colonies and mating apiaries, queen banking, and catching and caging queens. Topics will also include marketing and movement regulations, selling packaged bees and developing localised breeding calendars of operation). Importing bee semen for artificial insemination of queen bees by technical specialists of the project will also be investigated where appropriate following field assessments of feasibility).

1.4 Investigate the use of plastic frames/foundation and alternative wood frame configurations (e.g. stick frames) to overcome the wax foundation shortage and manage pest and disease (particularly wax moth) and encourage development of support industries.	Set up trial hives using participatory action research approaches for farmers to determine the effectiveness, suitability and impact. Semi structured interviews will be used to guide questions relating to access of inputs and their perceived benefits and limitations.	Information provided to enable better decision support on frame selection. Side industries encouraged to produce appropriate hive hardware and dissemination of farmers findings and experiences amongst other beekeepers through existing beekeeping networks.	That ACIAR researchers, beekeepers will be willing to dedicate sufficient time to fully input into this process.	Improved pest management strategies, reduction in costs and access issues relating to wax foundation and therefore increased honey production.
1.5 Work with MDF PNG to advise on post-harvest quality management programs for producers and packers developing standards, certification and testing processes	Meetings and processing assessments will be conducted with MDF PNG and their partners to identify key opportunities and constraints. Training publications, workshops, and in-field participatory active learning amongst staff employed in the post harvest handling of honey will be conducted for development of practical skills.	A HACCP plan will be developed and plans for up-scaling current processing equipment technologies and methods will be provided in a report to MDF partners based on their needs. Certification pathways will be developed in this process. Quality assurance systems, including testing and record keeping processes, standards and certification developed according to local conditions and production in PNG[5].	That honey value chain networks will be able to dedicate sufficient time to fully input into these analyses.	Reduction of risks of contaminants and improved safety standards for bee products. This will be developed primarily for PNG (NGF and Mountain Honey). Improve management options for current post harvesting challenges (fermentation, contamination and crystallisation). This will be developed primarily for PNG (NGF and Mountain Honey)

[5] The system and processes will aim to ensure that honey is uncontaminated and has correct moisture content to prevent fermentation and spoilage. This will be achieved through the development of training publications, workshops, and in-field participatory active learning for development of practical skills. Topics will cover all aspects of developing quality bee products with assurance systems, using a production-to-consumption systems model that identifies points along the production chain where quality may be lost. This includes the development of training publications for quality control for harvesting and post-harvesting practices, for beekeepers, processors and packers. Topics will include harvesting periods, moisture control by appropriately timed harvests, issues of supplementary feeding and adulteration, hygienic practices for processing and handling, and ‘best practice’ extracting, straining, melting, storing and processing of honey bee products.

1.6 Commence a process of spatial and temporal mapping of floral resources available for beekeeping in Eastern Highlands Province of PNG and Viti and Vanua Levu in Fiji.	Work with Forestry Departments and Universities to develop baseline maps. Key informant interviews and diaries with local beekeepers identifying the spatial and temporal distribution of flowering events in their region. Pollen trapping will be conducted in 4 major flora types for bees (i.e. coffee plantations, natural forest areas, grasslands and urban areas) in the Eastern Highlands in PNG and in Vanua Levu and Viti Levu in Fiji. Bee collected pollen will be sorted and analysed for protein content to determine the value of pollen resources to bees in these areas. This will also help in the development of floral calendars. A PAR approach to collection of pollen will be used for capacity building amongst 4 beekeepers in each of the floral types.	Floral calendars developed as spread sheets and also 'farmer friendly' information forms to inform periods of availability of major nectar and pollen sources relevant to improving honey bee management through improved understanding of honey bee nutrition[6].	Limited participation	Regional floral calendars developed to assist beekeepers to manage their hives effectively so as to maximise honey production during major honey flows. This will also help to improve survival rates of colonies during dearth periods. This information will be developed with local beekeepers, beekeeping associations, extension agents, and university organisations.

Objective 2: Improve control of diseases that constrain production and trade of bees, honey and other bee products

Actions	**Method**	**Output and milestone**	**Risks / Assumptions**	**Applications of outputs**

[6] Information will be collated, analysed and developed into the through community beekeeper consultation, key informant interviews, in-field observation, pollen and nectar identification and analysis, and by using localised floristic mapping.

2.1 Develop an appropriate system of best practice for pest and disease managementstrategies for *Varroa* and *Tropilaelaps* in PNG to inform 'best practice' should there be an incursion in Fiji, Solomon Islands or the Australian mainland.	Identify current management of pest and diseases that are being implemented. This will be conducted through field days and through workshopping techniques with beekeeping clubs. Evaluate current effectiveness of management practise using key informant interviews, workshopping with beekeepers, field trails and PAR. Evaluate pest and disease population parameters to inform timing for management applications. Populations will be monitored using PAR approaches with skilled farmers. Identify culturally appropriate and optimal pest and disease management strategies. This will be done by identifying the capital assets available to beekeepers through workshops and during household surveys to identify constraints (i.e. access to treatments or limited finance to afford) and how best to overcome them. treatments)	Pest and disease management programs relevant to local conditions for each country[7]. List of current procedures, practices and methods June. Qualitative and quantitative data regarding management strategies effectiveness and their perceived benefits and limitations. Identification of peak pest and disease periods to inform timing for treatments. Culturally appropriate management options will be identified.	Risks: Management options may not be used appropriately or have poor uptake which could reduce effectiveness Assumption That a culturally appropriate and cost effective method will be developed to manage relevant pests and diseases.	Best practice management will be incorporated into extension, education and training within beekeeping associations and universities. Best practice management developed can be used to inform Australian and Pacific Island countries biosecurity training, response and management procedures. This information will be provided to the Australian Honey Bee Industry Council and presented at national conferences.

2.2 Develop appropriate in-country honey bee pest and disease screening and monitoring protocols to identify existing honey bee pathogens and educate on the associated biosecurity threats posed. .	BAF and MAL staff trained to collect and analyse samples to determine presence, absence and distribution of honey bee pests and diseases.	List of key pest and disease pressures facing the industry and their perceived impact. June 2019 Data to inform pest and disease status, including distribution maps for Fiji, in particular for AFB and mites.	Risks: Incorrect information provided or lack of access to relevant information. Pathogens not detected or are missed due to the locations sampled.	Improved understanding of new and existing pests and diseases including their distribution in PNG and Fiji. Provide biosecurity information for Australian and Pacific region honey bee industries. This information will be provided to the Australian Honey Bee Industry Council and presented at national conferences.

[7] These will be developed through training publications, workshops and in-field participatory training using a participatory action research approach to enhance understanding of pests and diseases and develop practical identification and management skills. Topics will cover all aspects of pest and disease management, including species identification, monitoring, chemical and non-chemical management, hygiene, safety, and biosecurity relevance. In particular, the project will assess mite management strategies for *Varroa* and *Tropilaelaps* in PNG as a test case of 'best practice' if *Tropilaelaps* were to enter Fiji, Solomon Islands or the Australian mainland.

2.3 Develop an appropriate system of best practice for pest and disease management. Notably management of AFB in Fiji to inform 'best practice'.	Identify current management of pest and diseases that are being implemented. Evaluate current effectiveness of management practise using household surveys, field observations. Evaluate pest and disease population peaks to inform timing for management applications. This will be conducted using key informant interviews and workshops with smallholder beekeepers. Identify culturally appropriate and optimal pest and disease management strategies and incorporate these into training.	Pest and disease management programs relevant to local conditions for each country[8]. List of current procedures, practices and methods. Qualitative and quantitative data regarding management strategies effectiveness. Identification of peak pest and disease periods to inform timing for treatments. Culturally appropriate management options will be identified with uptake being measured with follow up surveys	Risks: Management options may not be used appropriately or have poor uptake which could reduce effectiveness. Assumptions: That a culturally appropriate and cost effective method will be developed to manage relevant pests and diseases.	Best practice management will be incorporated into extension, education and training for beekeeping associations and extension agents. Best practice management developed can be used to inform Australian and Pacific Island countries biosecurity training, response and management procedures.

[8] These will be developed through training publications, workshops and in-field participatory training using a participatory action research approach to enhance understanding of pests and diseases and develop practical identification and management skills. Topics will cover all aspects of pest and disease management, including species identification, monitoring, chemical and non-chemical management, hygiene, safety, and biosecurity relevance. In particular, the project will assess mite management strategies for *Varroa* and *Tropilaelaps* in PNG as a test case of 'best practice' if *Tropilaelaps* were to enter Fiji, Solomon Islands or the Australian mainland.

Objective 3: Build capacity of extension and development agencies to support beekeeping as a platform for sustainable small enterprises

Actions	Method	Output and milestone	Risks / Assumptions	Applications of outputs
3.1 Improve extension, education and training to integrate developed best practice pest and disease management into the beekeeping industry.	Conduct and evaluate train the trainer programs, current extension practices in the field and existing educational materials and teaching resources for improved content and delivery effectiveness.	Disease identification kits and training modules for identification and management of bee pests and diseases. Development of pest and disease educational materials, training workshops that are translated into local languages.	That educational materials are not adopted.	Development of industry standards, guidelines, training, awareness, information dissemination, educational and training materials and improved effectiveness of extension services, beekeeping clubs and support networks (i.e. private sector and aid organisations)
3.2 Review current beekeeping extension and training modules from relevant beekeeping training organisations to determine if they reflect 'best practice'.	Key stakeholder meetings, workshops, seminars and key informant interviews. Household surveys will inquire into perceptions and experiences in regard to extension provided by key beekeeping agencies	Report and compilation of current and past training materials and their application. Revised beekeeeping educational materials for relevant beekeeping training organisations.	That ACIAR researchers, government agencies and agribusine ss will be willing to dedicate sufficient time to fully input into this process, and associated risks of researcher/ business biase s.	Support the development of training and extension support materials for beekeeping associations and extension agents that reflect 'best practice' management using appropriate media.

3.3 Enhance extension capability specifically to support entry of women and families into the industry.	Employ one female entomologist/ researcher (CIC) Employ at least one female trainee extension Officer (NDAL). Develop women's mentorship initiative with local beekeepers clubs to link NGO gender and livelihoods programs. Key informant interviews and associated household surveys of women's beekeepers to determine women's engagement and constraints to their involvement in bee club activities. Training in the development of inputs and value-added products.	Female researcher and extension trainee employed in PNG and Fiji. Gender-specific training programs that overcome issues identified by key informants and women beekeepers for beekeeping, business management and the production of inputs and value adding of bee products. Manual for the development of value added honey bee products including candles, soaps and lip balms.	Risk: Competition from shop traders importing beeswax products. Stimulating jealousy and antagonism from other community members or existing experienced technical officers Limited participation or access to additional materials needed to make such products (i.e. lye, oils etc.).	Mentorship initiative will help to ensure a non-threatening environment and the provision of role models for gender inclusion. Women's mentorship initiative will optimise potentials for women's learning and engagement during training activities conducted 4 times annually. Improved options for income diversification though value added products form beeswax and propolis.
3.4 Develop policy recommendations for the establishment of a PNG beekeeping industry body, by convening and supporting discussions among beekeeper groups and government agencies.	Engage Government officers/policy and decision makers, Australian Beekeepers, Biosecurity staff (PNG) in discussions on policy recommendations through beekeeping industry stakeholder workshops.	Draft policies for registration of PNG beekeeping as an official industry association. Draft recommendations for Australian Government for Beekeeping to be recognised as an eligible occupation under the Australian Seasonal Worker Programme.	Limited participation. Non-acceptance of recommendations.	Facilitate registration of PNG beekeeping as an official industry association Beekeeping recognised as an eligible occupation under the Australian Seasonal Worker Programme.

3.5 Develop stronger local beekeeping clubs & associations that can support smallholder industry development.	Support in country extension agents and existing local beekeeping associations through the formation of district beekeeping clubs. This will include the facilitation of workshops for discussing mechanisms for collaborative district enterprises and the sharing of resources. Development of appropriate local communication channels[9] through existing radio stations, phone communications with beekeepers and associated clubs and media releases in local newspapers and education materials.	Active national association and regional clubs/ cooperatives with capacity to process and market their bee products.	A non-cooperative approach is adopted.	Improved access to beekeeping equipment, educational materials and extension. This will be conducted in collaboration with the Fijian Beekeepers Association and the Eastern Highlands Beekeepers Association.

[9] Appropriate local communication channels will be established (e.g. development of group 'Facebook' pages, online discussion boards, text message groups, 'Honey Hotlines' to extension officers, newsletters, and facilitation of group meetings by providing materials and by establishing groups in the initial phase of the project in each country.

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10.1 List of publications produced by project

Cooper Nat Schouten & David John Lloyd (2019) Considerations and Factors Influencing the Success of Beekeeping Programs in Developing Countries, Bee World, DOI: 10.1080/0005772X.2019.1607805

Under review:

John Roberts, Cooper Schouten, Reuben Sengere, John Jave and David Lloyd (2019) Different strategies to manage *Varroa jacobsoni* and *Tropilaelapse mercedesae* in Papua New Guinea, Journal of Apicultural Research.

Cooper Schouten (2019) Factors influencing beekeeping income and productivity in developing countries – a scoping review, Journal of Apicultural Research.

Annelise Austin, Cooper Schouten, Katja Mikhailovich and David Lloyd (2019). Limitations to women's participation in beekeeping enterprises in the Eastern Highlands Province of Papua New Guinea.

Jordanna Hintona, Cooper Schouten, Anneliese Austin and David Lloyd (2019). An Overview of Rural Development and Small-scale Beekeeping in Fiji.

11 Appendixes

11.1 Appendix 1: Mite management information sheet developed for smallholder beekeepers in PNG

Varroa and *Tropilaelaps* mites in Papua New Guinea

Varroa jacobsoni is the size of a pin-head, brown in colour and slow moving. They can live on adult bees for weeks but need brood to reproduce. They are most easily found by doing a 'sugar shake' or uncapping drone brood.

Tropilaelaps mercedesae are half the size of *Varroa*, brown in colour and fast moving. They cannot feed on adult bees and need brood to survive. They are most easily found by uncapping worker brood, especially from frames with signs of 'bald brood'.

11.2 Appendix 2: Honey Prices and Producers in the Eastern Highlands Province, PNG

There are four main honey suppliers in EHP in 2018 (Table 12). These are Highlands Honey, Mountain Honey, PNG Organic Honey and Capilano honey. The mean cheapest honey available is Highlands Honey 440gms at K39.77/kg, followed by HDVC (currently not readily available on shelfs). Some of the more expensive honeys on the shelf are local Mountain Honey and PNG Organic Honey. All local honeys are in high demand. There a number of poorly packaged honey brands, imported and honey imitations that threaten the honey sector (Figure 38).

Table 12: Price per kg for honey products available in Goroka, EHP – 2018.

Origin	Type	Volume (gm)	Average K	Price per Kg (K)	Container	PNG Made Logo?
PNG	Highlands Honey	440	17.50	39.77	Glass Jar	√
PNG	Henagaru Village Development Co-op	300	12.00	40.00	Plastic Jar	x
PNG	Henagaru Village Development Co-op	350	14.00	40.00	Plastic Jar	x
PNG	Henagaru Village Development Co-op	400	16.00	40.00	Plastic Jar	x
PNG	Henagaru Village Development Co-op	450	18.00	40.00	Plastic Jar	x
PNG	Henagaru Village Development Co-op	500	20.00	40.00	Plastic Jar	x
PNG	Henagaru Village Development Co-op	550	22.00	40.00	Plastic Jar	x
PNG	Henagaru Village Development Co-op	600	24.00	40.00	Plastic Jar	x
PNG	Henagaru Village Development Co-op	650	26.00	40.00	Plastic Jar	x
PNG	Henagaru Village Development Co-op	700	28.00	40.00	Plastic Jar	x
PNG	Highlands Honey	350	14.37	41.05	Glass Jar	√
PNG	100% pure local organic honey	500	20.90	41.80	Plastic drink bottle	x
Import	Capilano pure Australian honey	750	31.90	42.53	Plastic Jar	x
PNG	Highlands Honey	550	24.00	43.64	Squeeze	√
Import	Capilano light and mild	340	16.00	47.06	Squeeze	x
Import	Capilano pure Australian honey	500	24.45	48.90	Plastic Jar	x
Import	Capilano yellow box	375	18.50	49.33	Squeeze	x
Import	Capilano pure Australian honey	250	12.90	51.60	Plastic Jar	x
Import	Capilano pure Australian honey	220	11.90	54.09	Squeeze	x
PNG	100% pure local organic honey	1000	55.00	55.00	Plastic drink bottle	x
PNG	Mountain Honey	350	19.90	56.86	Plastic Jar	x
Import	Capilano pure Australian honey	500	29.50	59.00	Squeeze	x

PNG	PNG Organic Honey	250	14.90	59.60	Plastic Jar	√
Import	Capilano pure Australian honey	375	22.80	60.80	Squeeze	x
Import	Capilano natural floral Manuka honey	340	20.90	61.47	Squeeze	x
Import	Capilano creamed honey	500	49.90	99.80	Plastic Jar	x

Figure 38: Sugar adulterated, imported and poorly marketed honeys that threaten the PNG beekeeping industry.

11.3 Appendix 3: Mite Trial Data Sheet

Table 13: Mite management experiment data sheet.

Date: Name:
Location ID:

Bee Hives - Technology						Nutrition			
Hive No.	Strength (frames of bees = top + bottom/ 2)					Honey	Nectar	Pollen	
	1		2		3	No. Frames, Capped %	None, Light, Flow	Frames	Interface (cells)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

Date: Name:
Location ID:

Pest & Diseases								Notes	
Hive No.	*Varroa*			*Tropilaelapse*			Other Pests and Disease Obs.	Bald Brood + No. dead bees @entrace	Past mite management?
	Sugar Shake	Uncap	Bump	Sugar Shake	Uncap	Bump			
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

11.4 Appendix 3: Sticky Mat Data Sheet

Example of data from a single sticky mat from 24hr natural mite fall. A total of 81 mites found - 18 *Varroa jacobsoni* and 63 *Tropilaelaps mercedesae* (Table 14).

Table 14: Sticky mat data sheet.

	A		B		C		D		E		F		G		H		I		J		K	
	V	T	V	T	V	T	V	T	V	T	V	T	V	T	V	T	V	T	V	T	V	T
1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	2
3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
4	0	0	0	0	0	0	0	1	1	1	0	1	0	1	0	0	1	0	0	1	0	1
5	0	0	0	1	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
7	0	0	0	0	0	2	1	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	1	0	0	0	1
9	1	0	0	0	0	1	0	0	0	0	2	1	0	1	0	1	0	0	0	0	0	0
10	1	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
11	0	0	0	1	0	0	0	0	0	1	0	1	0	2	0	0	0	0	0	2	0	1
12	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0
13	0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
14	0	1	0	0	0	1	0	0	0	0	0	0	0	2	0	0	1	1	0	1	0	0
15	0	0	1	0	0	1	0	1	0	1	0	3	0	1	0	1	0	0	1	0	0	0
	2	2	3	2	1	9	1	4	2	4	2	12	0	11	2	5	2	4	3	5	0	5
	2		3		1		1		2		2		0		2		2		3		0	
		2		2		9		4		4		12		11		5		4		5		5

Hive ID# GH3	Date Installed: 16/5/18	Date Removed: 17/5/18

11.5 Appendix 4: Alternative miticide options

Table 15: List of alternative chemical options for ensuring rotation, their effectiveness and potential risks the apiculture sector in PNG.

Chemical	**Brands™**	**Treatment**	**Effectiveness**	**Risks**
Tau-fluvalinate	Apistan, Maurik, Apilife, Amatraz	1 strip per 5 frames of rood		Can negatively affect brood and drones
Coumaphos (organophosphate)	Checkmite+, Asuntol® Perizin®			Can negatively affect queen bees
Flumethrin	Bayvarol®	2 strips per 5 frames of brood		
Oxalic Acid Dihydrate		Dribble or spray	Since it is not lipid (fat) soluble, it will not build up in the wax of the combs. It is a natural component of honey, and treatment with oxalic does not appreciably increase the concentration of it in honey (Brødsgaard, 1998). It is safe and easy to apply	
Formic Acid				Can negatively affect brood
Thymol				Can negatively affect brood