The Shifting Seasonality of Beekeeping with Climate Change

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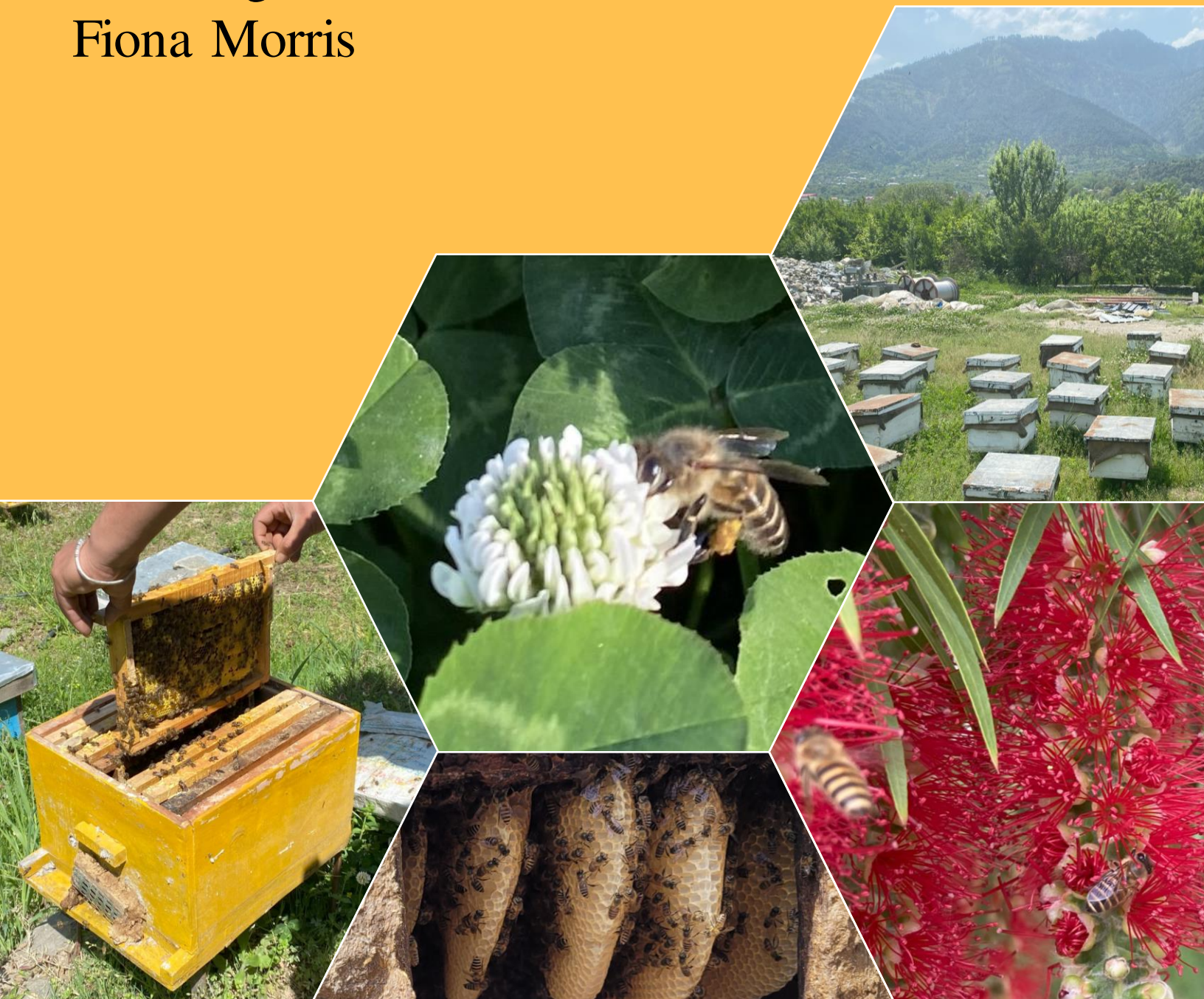

The Shifting Seasonality of Beekeeping with Climate Change

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by
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Abstract

Beekeeping in Himachal Pradesh, India has shifted away from indigenous methods and towards industrial methods to increase productivity. As the region urbanizes and agricultural methods change, beekeepers are facing new and increasing challenges. Beekeepers using more intensive industrial methods and at higher altitudes are also increasingly challenged by climate change. We set out to learn about the effects of climate change on beekeepers over the last 10-20 years. However, beekeepers were primarily concerned with the effects of urbanization and agriculture on their bees' health and honey production. As conditions in Himachal Pradesh change, industrial methods and migratory beekeeping are crucial for increasing productivity, although indigenous methods are more resilient to climate change.

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Executive Summary

Introduction

People, especially those in agricultural professions, look to the weather and environmental conditions to define the seasons of their year. As climate change causes more unpredictable weather phenomena, the seasons we are familiar with are shifting, forcing established schedules to adapt. We aimed to examine how these forces are causing shifts within the profession of beekeeping in Himachal Pradesh, a vital industry both for bee products, but also for the important pollination services they provide to crops (Chaudhary & Chand, 2017). We also sought to learn how beekeepers are adapting to changes and how these adaptations are influenced by their local context.

Background

Himachal Pradesh is a mountainous and climatically varied state, ranging from low plains to high hills. Climate change in Himachal Pradesh has resulted in increased average temperatures, decreased rainfall, and shorter winters (R. S. Rana et al., 2011). The high altitudes and glacial river basins of Himachal Pradesh make it especially vulnerable to the effects of climate change. Climate change impacts beekeeping primarily by impacting the blooming and nectar production of flowers, resulting in less food available for the bees.

Beekeeping has a long history in the region of Himachal Pradesh, relying on a local honeybee, *Apis cerana*, in either fixed wall hives, log hives, or mud hives. This native bee is well adapted to the cold conditions of the mountains, and requires less flora and maintenance than the otherwise more productive *Apis mellifera*, the Italian honey bee used commercially worldwide. Indigenous beekeeping methods often require little maintenance and care, and are heavily used by "hobbyist" beekeepers, farmers and other residents of Himachal Pradesh with agricultural professions that keep bees for personal use of their products or as a limited source of income.

The emergence of several key technologies in the mid-1800s resulted in what we call "industrial beekeeping", which uses box hives and other tools to ease beekeeping tasks such as extracting honey and monitoring or cleaning the hive. These methods have been adopted by beekeepers to increase income, with support of government initiatives and agricultural universities. These technologies also enable an entirely new mode of beekeeping, migratory

beekeeping, where the colonies are continually moved to maximize honey production from the bees. This results in substantial increases in honey production, but requires the use of the *Apis mellifer*a and multiple substantial moves in a year.

As beekeeping has been impacted by the introduction of new technology, so have other industries in the region. In agriculture, the increasing use of monoculture and pesticides result in greater crop yields, but will harm and kill bees and bee colonies. Urbanization and road-building also impact the natural environment and can make less flora available for bees.

With the impact of climate change being felt all over the world, the CALENDARS project, led by Dr. Scott Bremer at the University of Bergen in Norway, aims to investigate the influence of culture on seasonal patterns and schedules. The project is aimed towards learning how culture and indigenous knowledge influences a society's ability to adapt to climate change. We have sought to extend the knowledge of the CALENDARS Project to India. To do so, we worked to answer the following questions to gather common data that could be compared between beekeepers around the globe:

1. How have beekeeping practices and technological tools that support beekeeping changed?
2. What is the future outlook for beekeeping as described now by beekeepers?
3. What climate change indicators and vulnerabilities are reported?

Methods

Our goal in this project was to evaluate the extent to which beekeeping schedules in Himachal Pradesh are affected by climate change. We sought to achieve this goal through the following three objectives:

1. Understanding Bee and Beekeeper Activity in Himachal Pradesh
2. Analyze and Present Beekeeper's Adaptations and Challenges
3. Evaluate Perceptions of Seasonality and Change in Response to Climate Change

To understand bee and beekeeper activity, we interviewed beekeepers, asking them about their yearly schedule and methods (tools, hive types, bee type, practices). To corroborate the information received from beekeepers, we interviewed scientists from Dr. Yashwant Singh Parmar University of Horticulture & Forestry for information about climate, pests, and apicultural practices. Lists of interview questions are available in the appendices E-G.

To determine beekeeper's adaptations and challenges, we collected data on the frequency at which different challenges were reported by beekeepers, as well as the perceived cause of

these challenges. We also determined from beekeepers the changes in their methods over time, the reasons behind these changes, and how they felt about the future outlook of their beekeeping.

To evaluate beekeepers' perceptions of seasonality and their change, we created visual calendars of the beekeepers' year and how they changed over the past 10-20 years, as well as examining trends in climate-related phenomena reported by beekeepers.

Results and Analysis

Climate change was primarily noticed by beekeepers as changes in temperature and rainfall. Temperatures were increasing overall, but they also reported that temperatures were more variable than they were in the past, changing the times when flowers bloom and making conditions more favorable for pests. Similarly, rainfall was reported as more variable, resulting in disruptions to flower blooming patterns and nectar production that bees rely on. Higher altitudes are more sensitive to changes in climate, thus beekeepers at high altitudes experience more hardships and notice them sooner than beekeepers at lower altitudes.

Beekeepers reported their bee populations decreasing over time, which makes the colonies more vulnerable to pests, especially wax moths. As a result of the decreased bee population and increased susceptibility to pests, honey production from indigenous Himachali beekeeping methods has decreased.

Indigenous methods and hive types are well adjusted to temperature variation and are low maintenance in comparison to industrial methods. As a result, some hobbyist beekeepers are switching back to indigenous methods. Migratory beekeeping on the other hand, is an industrial method that allows beekeepers to provide their bees ideal temperatures and abundant flora year round in order to increase honey production. Access to new information prompted some beekeepers to change their techniques. University or village-led trainings teach beekeepers about reducing pesticide exposure and supplemental feeding.

Increasing use of monoculture and agricultural expansion, as well as increased urbanization of Himachal Pradesh also has an impact on beekeeping. Monoculture farming reduces floral diversity, making food less available to bees at certain times, and agricultural expansion reduces the area that wildflowers can grow in, having a similar effect. Deforestation and road-building works also to reduce the diversity and quantity of flora, while concrete houses provide no space for indigenous wall hives, reducing the native bee population in the area.

Changing agricultural methods have brought increased use of pesticides, which beekeepers consistently reported as a major problem. Bees will die when exposed to pesticides, which reduces the strength of the colonies, making them more vulnerable to pests or poor conditions. Smaller colonies also produce less honey, and pesticides will lower honey quality. One beekeeper reported that if pesticide use increased, they may no longer be able to continue beekeeping. Migratory beekeepers reported planning their routes in order to avoid areas affected by heavy pesticide use.

While beekeepers divided the year based on established seasons, these seasons were not the same between beekeepers, and were also used to define different bee activities and plants available. However, methods have a heavy impact on how much beekeepers interact with bees. Beekeepers using indigenous methods can be very "hands-off", sometimes only opening their hives 4 times a year, making their use of bees not impactful enough to divide their year up from. On the other end of the spectrum, migratory beekeepers, using the most intensive method of beekeeping, would divide their year based on where they were and what plants their bees were foraging from. Most stationary beekeepers would however link bee activities to the seasons they reported. Some beekeepers reported small-scale shifts in seasons, 10-20 days, as well as changes in the times that various flowers bloomed, which could be shifted by up to a month.

The CALENDARS project has researched beekeeping in several locations around the world. Prior to our research in Himachal Pradesh, two research projects were completed in New Zealand and Hong Kong (Arroyas et al., 2024; Ehmer et al., 2024). We compared the key findings from these two projects with our data (Table 3). Each project sought to answer the following three questions:

1. How have beekeeping practices and technological tools that support beekeeping changed?
2. What is the future outlook for beekeeping as described now by beekeepers?
3. What climate change indicators and vulnerabilities are reported?

The practices and tools supporting beekeeping in Himachal Pradesh and New Zealand have changed in similar ways. In both Himachal Pradesh and New Zealand, supplementary food for hives has grown more common with changing floral availability, but in Himachal Pradesh this is due to decreased flora availability, but in New Zealand it is due to increased temperatures making bees more active. Similarly, in both places beekeeping has become more technical and scientific, and likely will continue to do so over time. Meanwhile, in the more urban environment of Hong Kong, there has been an increase in urban apiaries.

The future outlook for beekeeping differs between the three locations and is quite different. While beekeepers in both New Zealand and Himachal Pradesh are reliant on their

communities for information and training, New Zealand has formal organizations in place for beekeepers, while beekeepers in Himachal Pradesh rely largely on relationships with other beekeepers, with some additional support from government programs and agricultural universities. In Himachal Pradesh, the government has consistently supported beekeepers, but changing regulations in New Zealand have made beekeeping less profitable, driving some from the practice. In all three sites, there are concerns, but they vary depending on location. Himachali beekeepers are worried about pesticides most often, while New Zealand beekeepers reported concerns about Varroa mites, and beekeepers in Hong Kong are threatened by worsening environmental challenges.

Beekeepers in these three regions are impacted by similar changes in the climate. Himachali beekeepers are affected by increased temperatures and rainfall variability, which decrease nectar production in plants. Increased global temperatures have increased the impact of Varroa mites for beekeepers in New Zealand. Additionally, beekeepers in New Zealand are affected by increased rainfall and severe storms. Beekeepers in Hong Kong are experiencing weather fluctuations and observing the migration of native flora to higher altitudes as a result of increasing temperatures.

Conclusions

Overall, we found that the methods and location of a beekeeper impacts their perception of the climate. Beekeepers at higher altitudes or using more labor demanding methods were more likely to notice changes in their environment. However, climate change was not the most frequently reported challenge. According to local beekeepers, pesticides and the effects of changing agricultural methods and urbanization are the greatest threat to beekeeping in Himachal Pradesh. As the environment of Himachal Pradesh continues to change, either from climate change or urbanization, the productivity of beekeeping is expected to continue to decrease. Industrial beekeeping methods, especially migration, are crucial for increasing profit.

Chapter 1: Introduction

Shifting Seasons Around the World

We often look to the weather and environmental conditions to define the seasons of the year. As climate change causes differences in predictable weather phenomena, the seasons we are familiar with are shifting. With these shifting seasonal patterns, established schedules, both cultural and agricultural, are forced to adapt to this new reality. Timing of significant events by seasons is not a new phenomenon (Chisholm Hatfield et al., 2018), but is newly under threat from climate change. Environmental changes are particularly appreciable in agricultural processes, such as apiculture, also known as beekeeping. As bees are crucial pollinators for the health of ecosystems and agriculture around the world (Chaudhary & Chand, 2017), the consequences of climate change on bees poses challenges for both the ecosystems and humans that rely on them, whether for their products or for pollination. This heightened vulnerability to changes in the environment provides an opportunity to examine how adaptations to changing climate realities are impacted by local cultural and economic factors.

Beekeeping and Shifting Seasonality In Himachal Pradesh

Beekeepers raise and maintain colonies of honeybees in order to extract various bee products, either for sale or for personal use. Two different varieties of bee are used in Himachal Pradesh. The first is *Apis cerana* (*A. cerana*), the native Indian honey bee, and the second is *Apis mellifera* (*A. mellifera*), the European honey bee, which is used for beekeeping in much of the world. Though different species, their behavior is largely the same. When it is warm enough and environmental conditions are right, honeybees will leave their hives and forage nectar and pollen from flowering plants, which they return to the hive to serve as food stores in the form of honey. This food is stored in wax honeycomb structures built within the hive. If there are sufficient food sources and the weather is warm enough, the bee population will grow large and begin to swarm, attempting to find or create a new hive and split into two colonies. When the weather is cold out and food sources are scarce, bees will retreat to their hives and hibernate together for warmth, consuming the food stored within the hive until conditions are right to become active and begin foraging again. As bees will typically store more honey than they need to survive until they can begin foraging again, the excess honeycomb can be extracted by the beekeeper for beeswax and honey, the two main products of beekeeping. In addition to stationary beekeeping, where hives are kept in a fixed location, migratory beekeepers will continually move their hives of bees to

areas with suitable environmental conditions for foraging, to keep their bees constantly collecting honey.

As climate determines the behavior of bee colonies, beekeeping is thus heavily reliant on climate factors like the predictability of rainfall, plant flowering, temperatures, and more. Along with these factors, the traditions and status of beekeeping in Himachal Pradesh will heavily impact what the effects of climate change will be on Himachali beekeepers. Globally, climate change has resulted in a variety of effects on beekeepers, from lower honey production to increased threats to bee health (Sonika et al., 2021) (vanEngelsdorp et al., 2009). Beekeepers have applied a wide variety of changes in an attempt to adapt to this changing reality (Malisa & Yanda, 2016). In the Himalayas, where beekeeping has traditionally relied on wall-fixed hives, government initiatives have encouraged a shift away from these traditional methods and towards profit-making ones, often following global industrial agricultural methods using box hives with removable frames.

In Himachal Pradesh, colonies of *A. cerana*, which are kept in stationary hives, first become active towards the end of winter in response to increased temperature, sunlight, and plants beginning to flower. Foraging and brooding occurs throughout the spring. For a portion of the spring, colonies separate during swarming. The colonies become inactive again during monsoon season, leaving the hive on occasion for sunny days but not to forage. When heavy rains cease, the bees return to foraging. Depending on local conditions, the beekeeper will harvest honey during these periods of foraging. Decreasing temperatures indicate the beginning of winter when bees hibernate until the temperature increases and flowers begin to bloom again. An overview of this cycle is demonstrated in Figure 1. Stationary colonies of *A. mellifera* are not common but follow a similar cycle of active and dearth periods, according to the schedules reported to us by Himachali beekeepers. However, migratory beekeeping allows *A. mellifera* colonies to be active throughout the entire year. The colony broods, swarms, and produces honey all year because there is constant availability of flora (beekeeper 8, personal communication, April 21, 2024). Migratory beekeeping is only used with *A. mellifera*, as *A. cerana* colonies will abandon their hives if they are moved frequently (beekeeper 5, personal communication, March 29, 2024).

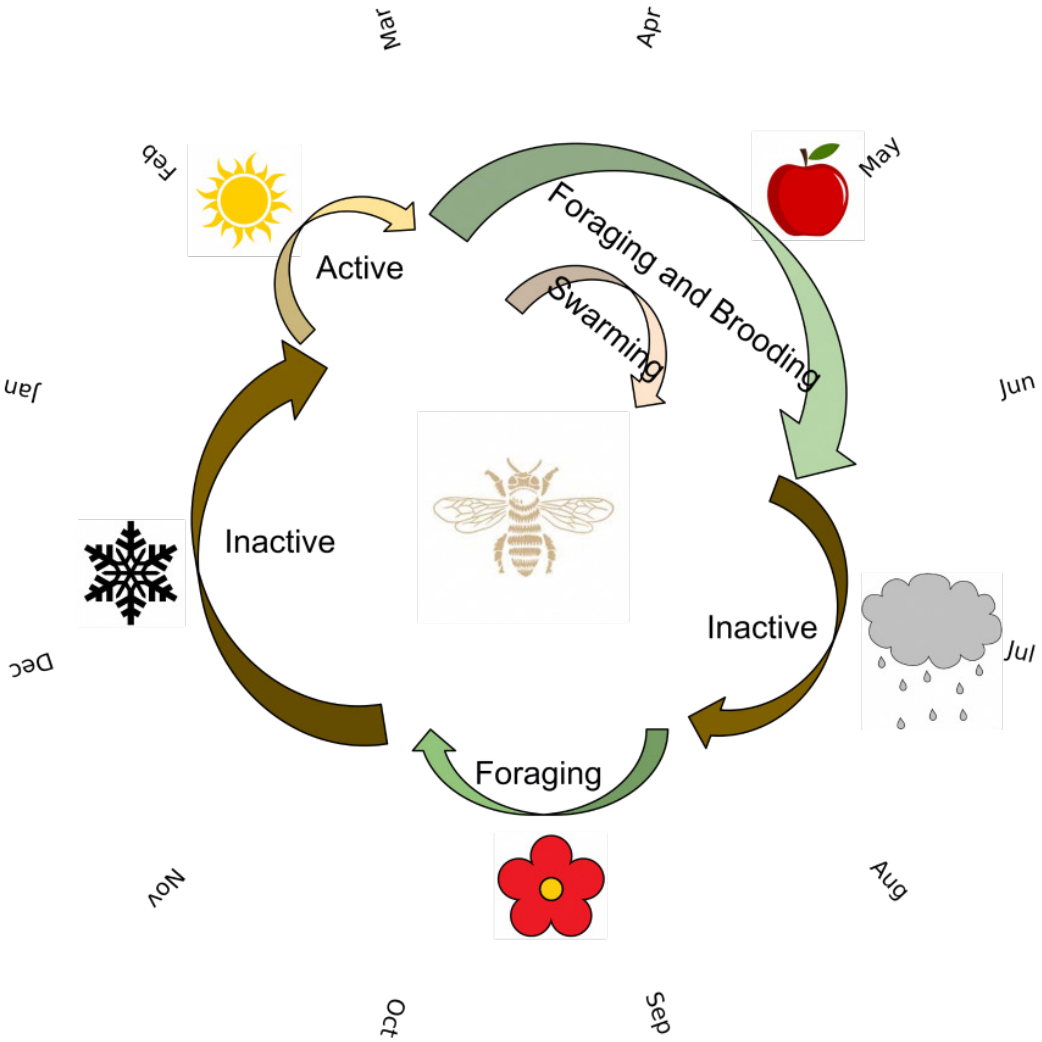

Figure 1: The yearly activities of *A. cerana* bees in Himachal Pradesh. The length of each activity is proportional to the duration of the year that each activity takes place according to beekeepers in Himachal Pradesh.

Mission Statement

We collected information about the ways in which beekeepers of Himachal Pradesh are perceiving and coping with change in order to increase understanding of how climate change and urbanization are affecting communities around the world.

Chapter 2: Background

Himachal Pradesh has mountainous terrain with a wide range of climates. Climate change has led to increased average temperatures, decreased rainfall, and shorter winters in Himachal Pradesh (R. S. Rana et al., 2011). Himachal Pradesh is home to many apple orchards and beekeepers, which are adversely affected by climate change. Beekeeping has a long history in the Himalayas, but as locals seek economic advancement, beekeepers have increasingly swapped indigenous beekeeping practices for industrial ones, sometimes referred to as "scientific beekeeping" (Narang et al., 2022). Indigenous beekeeping refers to the use of the native Indian honeybee and the hive types that have historically been used in Himachal Pradesh, while industrial beekeeping refers to the use of box hives and other tools, either with the European honeybee or the native bee. Various government initiatives to promote adoption of industrial beekeeping technology have occurred several times under British rule and after independence, the most recent with the establishment of the Khadi Village Industry Commission in 1962 (Narang et al., 2022). Beekeepers globally are experiencing decreased honey production and increased threats to the health of their bees as a result of climate change (Gajardo-Rojas et al., 2022; Malisa & Yanda, 2016). As climate change forces beekeepers in different regions to adapt, different adaptations are made depending on local geographic and cultural context.

Geography and Climate

Himachal Pradesh is a state in northern India comprised of 12 districts. Himachal Pradesh sits at the roots of the Himalayan mountains, with districts ranging from plains to high mountain valleys, as seen in Figure 2. This results in great variation in climate throughout the state (Upgupta et al., 2015). Its high altitudes and glacial river basins make Himachal Pradesh one of India's most vulnerable regions to climate change (Kulkarni et al., 2021).

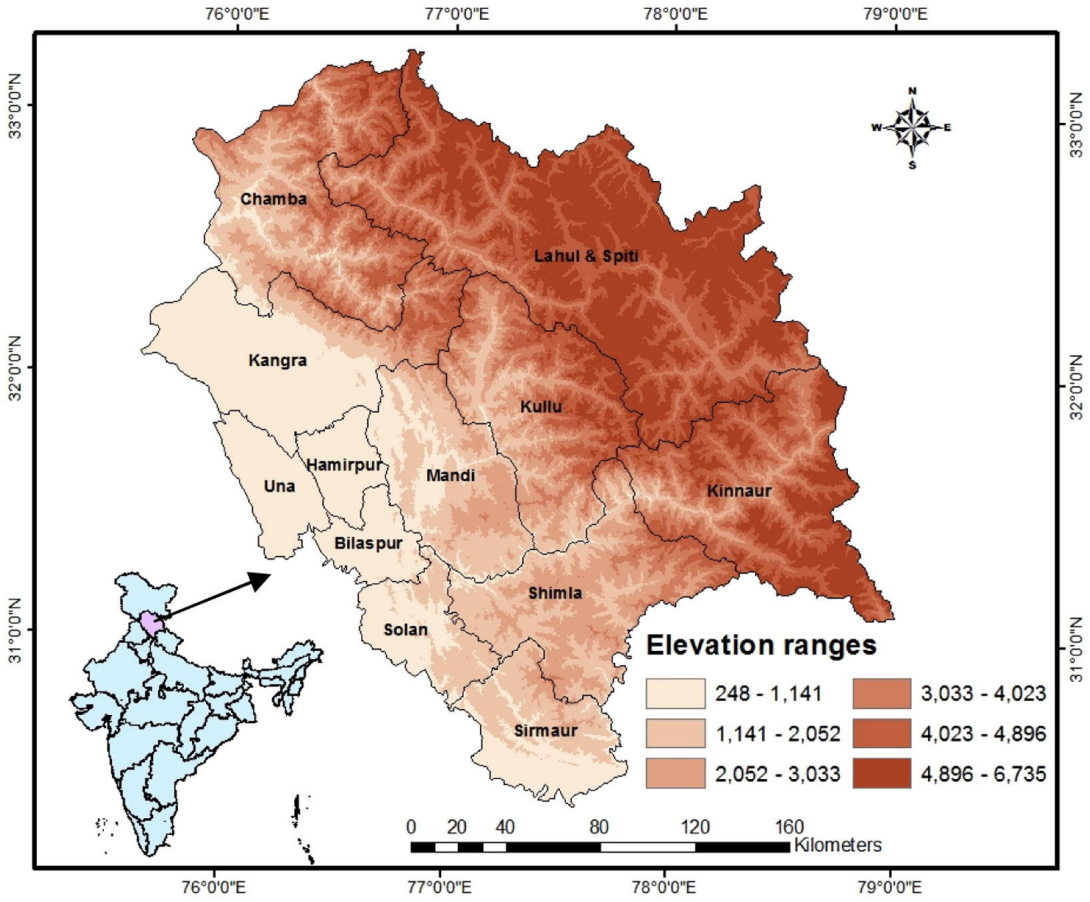

Figure 2: Elevation map of Himachal Pradesh (Upgupta et al., 2015).

Since 1901, 2022 was the second hottest year on record for Himachal Pradesh (Hosalikar, 2022). Compared to a long period average from 1981-2010, the annual mean land surface air temperature was 1.2°C warmer, the annual maximum temperature was 1.0°C warmer, and the annual minimum temperature was 1.3°C warmer (Hosalikar, 2022). In terms of statewide monthly rainfall, January had a large excess while March, April, and December had large deficits (Hosalikar, 2022). District-wide rainfall trends from 1901 to 2022 show a significant decrease over said period in rainfall for Chamba, Lahul and Spiti, and Kinnaur (Hosalikar, 2022).

Beekeeping Practices in Himachal Pradesh

Beekeeping practices in Himachal Pradesh have changed to cope with changes in the environment and new demands for productivity. These changes include the use of a different bee species and a shift away from traditional hive types.

Bee Species

The native species, *A. cerana*, was the only honey bee reared in Himachal Pradesh until 1961 when the Italian honey bee, *A. mellifera*, was introduced to the state (A. Sharma et al., 2022). In Kinnaur, small-scale fruit production relies heavily on colonies of *A. cerana* in wall-fixed hives (Beszterda, 2000), while large-scale agriculture utilizes both *A. cerana* and *A. mellifera* for maximum fruit production (Beszterda, 2000; Chaudhary & Chand, 2017).

While *A. cerana* are adapted to the Himachali climate, *A. mellifera* can't handle the cold winter temperatures, and they require more space and flora compared to *A. cerana* (H. K. Sharma, personal communication, April 17, 2024). Thus, beekeeping with *A. mellifera* is typically practiced as migratory beekeeping in Himachal Pradesh as it allows beekeepers to avoid cold temperatures and access more flora (A. Sharma et al., 2022). According to a 2001 survey of 60 beekeepers in Kangra, migratory beekeeping had a higher honey yield of 41.60kg/colony compared to stationary beekeeping at 15.66kg/colony (A. Sharma et al., 2022). According to another study in 2015, the average *A. mellifera* colony produced 20kg of honey per colony whereas *A. cerana* produced 3 kg of honey per colony (A. Sharma et al., 2022). The higher honey yield of *A. mellifera* was likely due to their being raised using migratory beekeeping methods. *A. cerana* are not suited for migratory beekeeping.

According to literature, past attempts to modernize beekeeping in the Himalayas failed, largely because the new technologies that scientists attempted to introduce were unsuitable for the region (Beszterda, 2000). More recently however, migratory beekeeping with *A. Mellifera* and modern box hives has become more widespread and is increasing in popularity as beekeepers look to increase their honey production.

Indigenous Beekeeping

Indigenous beekeepers in Himachal Pradesh keep *A. cerana*, the native Indian honey bee, colonies in a variety of different hive types. Log hives known as "dhindhor" in Kullu valley are made by hollowing out tree trunks of trees such as Pinus wallichiana and Picea smithiana (A. Sharma et al., 2022). According to Beszterda, vertical and horizontal log hives are also common in Kinnaur (Beszterda, 2000). However, we did not observe horizontal log hives in our research. Vertical log hives are made of hollowed tree trunks often placed on solid wooden or stone hive stands (Figure 3). Wooden covers are often used to close the upper hole, but metal covers are increasingly common as of the 1990s (Beszterda, 2000).

Figure 3: Log hives in Gumma (left) and in Naggar (right).

Wall-fixed hives are the most common beekeeping method in the mountains of Himachal Pradesh (Beszterda, 2000). The hives are mounted directly into the walls of houses or barns (Figure 4). Wooden covers are used as thermal protection, and the front facing panel is often adorned with decorative carvings (Beszterda, 2000). In Chamba, these wall hives are known as "Ganari" (A. Sharma et al., 2022). In Sirmaur, wall hives are sometimes called "Tira" (Kumar & Thakur, 2014). According to a survey of 117 households in the Sirmaur region, there were an average of 2.92 hives per house, and 72.32% of interviewees reported learning their beekeeping methods from their forebears (Kumar & Thakur, 2014). The inside of the wall hive is usually wood, slate, or stone and plastered with mud and cow dung, the hive is only ever opened to harvest honey (Kumar & Thakur, 2014). Many beekeepers spread beeswax on the opening of the wall hive to attract local bee populations.

Figure 4: Wall hives from Chama (left) and Gumma (right).

Mud hives are stationary box-like structures made for stationary beekeeping. This hive type has been developed in response to increasing demand for them in Shimla and Kullu (R. K.

Daroch, personal communication, April 2, 2024). Some mud hives in use at YSP University and by a beekeeper are shown in Figure 5.

Figure 5: A fixed mud hive at YSP university apiary (left), a mud hive with an back open, enabling access to the honeycomb and bees inside in Naggar (middle, right).

The Status of Indigenous Beekeeping in Himachal Pradesh

In the Sangrah block of Sirmaur, 52.35% of colonies had not been deserted in the past 20 years, this percentage was only 14.6% in the Pachhad block due to prevalent drought conditions (Kumar & Thakur, 2014). Most of the Sirmaur beekeepers interviewed did not feel the need to supplement their hives with food during dearth periods, only 8.65%, mostly beekeepers who sold their honey, supplemented their hives (Kumar & Thakur, 2014). However, 67.91% of beekeepers would only harvest a portion of the honey, leaving about one third for the bees (Kumar & Thakur, 2014).

Industrial Beekeeping

Industrial beekeeping only began to emerge in India and the world in the mid 1800s. Previously, harvesting a hive was a destructive process that involved squeezing the comb to extract the honey, effectively destroying the hive. However, with two key innovations, the non-destructive harvesting of hives was enabled. The first is removable frames and bee space, allowing the extraction of honeycombs from hives while leaving the bee population of the hive intact - these are used in so-called “box” hives, which can be seen in Figure 6. The second is honey extractor, which allows removing honey from honeycombs without destroying the comb (Ghosh, 1994, p. 10). Another practice seen in beekeeping in transhumance, or migratory beekeeping. This involves moving bee colonies throughout the year to different locations, allowing the bees to take advantage of different climatic conditions and different flora to increase honey production and keep the colony healthy (Brar et al., 2018). Migratory routes vary based on

the beekeeper's starting location (H. K. Sharma, personal communication, April 17, 2024). An overview of the main flora in different locations is represented in Table 1.

Figure 6: Wooden box hive in Gumma (left) and migratory box hives being rented to an orchard in Bajaura (right).

Migratory beekeepers in Himachal Pradesh use *A. mellifera* bees, and will move their colonies throughout the year to other states such as Haryana, Punjab, and Rajasthan (Table 1).

Table 1: Migratory cycles of *A. mellifera* adopted by beekeepers in Himachal Pradesh (Negi et al., 2020).

District	Period	State	Major honey source
Kangra	September-November	Punjab, Rajasthan	Mustard
	December- February	Haryana	Eucalyptus
	March- April	Himachal Pradesh	Apple
Kinnaur	October- February	Punjab, Haryana	Mustard, Eucalyptus
	March- April	Himachal Pradesh	Apple
Solan	November-December	Punjab, Rajasthan	Mustard
	January- February	Haryana	Eucalyptus

Global Effects of Climate Change on Apiculture

Honey production has declined in many parts of the world. Climate changes have also affected comb size, bee foraging, and other factors because variable temperatures and rainfall adversely affect bee health and floral availability (Sonika et al., 2021). Apiculture is also affected by its relationship to agriculture because pesticides from adjacent agriculture affects bees through

their nectar sources and the use of land for agriculture influences what flora are available in the area. Apicultural regions of Himachal Pradesh share resources with apple orchards and fields of non-native crops like plum and apricot, so bees are increasingly exposed to chemical pesticides and insecticides as well as non-native flora.

Nectar production is adversely affected by dry spells and intense, erratic rains. Changes in rainfall impact soil moisture, which impacts nectar production in wild flora and crops (H. K. Sharma, personal communication, April 17, 2024). Nectar is an essential source of energy for bees and is therefore a crucial component of colony health.

Effects of Urbanization on Apiculture

Urbanization has adverse effects on beekeeping in Himachal Pradesh. Intensive agriculture and pesticide use negatively impact foraging and bee health.

Intensive Agriculture

Increased average global temperatures has increased pest problems globally, so the agricultural industry is increasingly dependent on chemical pesticides and insecticides. As temperatures continue to increase, pests develop resistance to chemicals, and agriculture becomes more intensive, the agricultural industry has to use new and more pesticides and insecticides (R. K. Daroch, personal communication, April 2, 2024). Furthermore, the practice of monoculture farming decreases flora diversity, and overall flora availability for the bees. Intensive agriculture also frequently requires the use of chemical pesticides, causing problems for bee colonies.

Pesticides

The impact of pesticides on bees is a relatively new phenomenon on which limited conclusive research has been done. Colony collapse disorder describes the unexpected losses of *A. mellifera* colonies in the United States (vanEngelsdorp et al., 2009). The main trait of colony collapse disorder is the rapid loss of adult worker bees. Other traits include delayed pest invasions and kleptoparasitism from neighboring colonies.

Chemical pesticides can weaken the immune system of honey bees, increasing the colony's vulnerability to pathogens. Honeybees have significantly fewer detoxification enzymes

compared to other insects, decreasing their resistance to pesticides. However, there is no conclusive evidence that pesticides increase a colony's vulnerability to colony collapse disorder. Increased pesticide usage for industrial agriculture disrupts bee foraging behavior (vanEngelsdorp et al., 2009). In addition to pesticides, bees are adversely impacted by other contaminants. Exposure to pollutants has led to higher metal content in bee products (Sonika et al., 2021).

Regulatory authorities in several countries are working towards revising their national assessments to evaluate the safety of pesticides to bees (Maus et al., 2016). A risk assessment based on the principles of the European and Mediterranean Plant Protection Organization 170 Approach, which is successfully used in Europe, has been considered a feasible system for other parts of the world (Maus et al., 2016).

Deforestation and Road Building

The ecological consequences of increasing urbanization and construction often adversely affect apiculture. Deforestation for road building depletes a region of its wild flora, decreasing floral density and diversity (H. K. Sharma, personal communication, April 17, 2024).

The CALENDARS Project

The CALENDARS Project is led by Dr. Scott Bremer at the University of Bergen to investigate the influence of cultures on seasonal patterns and schedules. The CALENDARS Project explores the different ways people perceive changes in seasonal patterns. The project seeks to understand how a culture's calendar of the seasons helps or hinders a society from adapting to changing seasonal patterns caused by climate change. Beekeeping is one of the lenses through which the CALENDARS Project explores this topic. To do this, the CALENDARS Project has employed a calendar tool that allows users to input their schedules on a linear outline of the year (Hayden et al., 2022). The tool is intended to allow users to enter their schedules to add to the CALENDARS project website, which gathers information and makes it available to the public. However, the calendar tool is not currently functional enough to be publicly hosted. The project has collected some seasonal diaries from Norway and New Zealand over the past 5 years, documenting the climatic changes observed during the COVID-19 lockdown. The project includes a collection of blogs from Japan, New Zealand, Norway and more discussing the foods, clothing, and traditions that people associate with each season.

We have sought to extend the knowledge of the CALENDARS Project to India. To do so, we worked to answer the following questions to gather common data that could be compared between beekeepers around the globe:

1. How have beekeeping practices and technological tools that support beekeeping changed?
2. What is the future outlook for beekeeping as described now by beekeepers?
3. What climate change indicators and vulnerabilities are reported?

Chapter 3: Methodology

Goal: Evaluate the extent to which beekeeping schedules in Himachal Pradesh are affected by climate change.

We achieved this goal through the following three objectives (Figure 7):

1. Understanding Bee and Beekeeper Activity in Himachal Pradesh
2. Analyze and Present Beekeeper's Adaptations and Challenges
3. Evaluate Perceptions of Seasonality and Change in Response to Climate Change

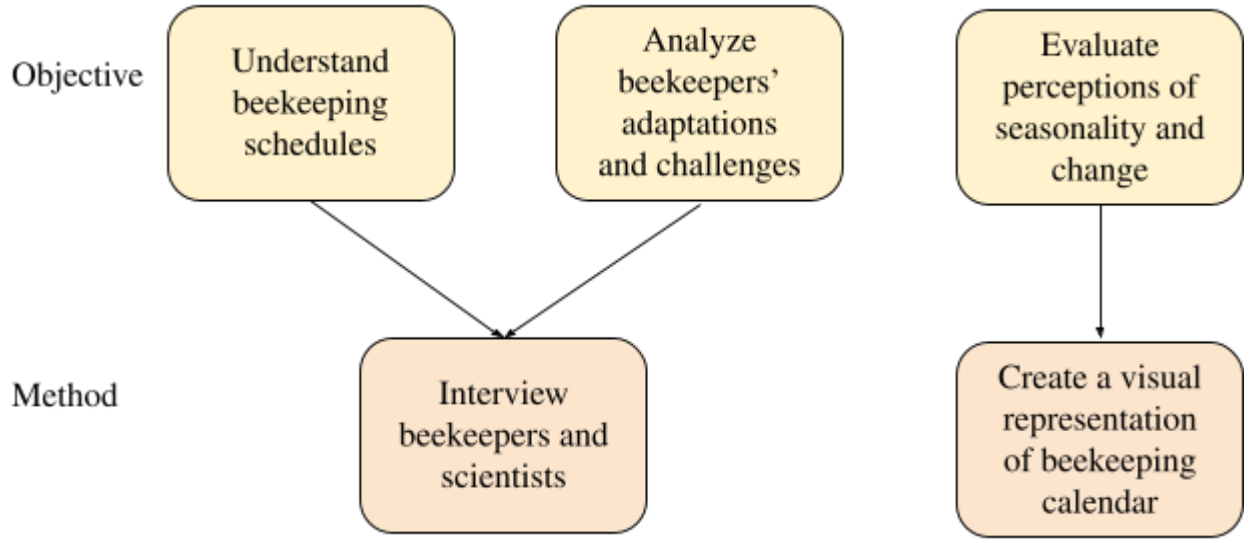

Figure 7: This flow chart demonstrates each project objective and the corresponding method used to achieve the objective.

Objective 1: Understanding Bee and Beekeeper Activity in Himachal Pradesh

We interviewed beekeepers in Himachal Pradesh to learn about the methods and tools they used and the trends in honey production and income over time, documenting the different hive types and tools each beekeeper used. We observed the quantity of hives each beekeeper had. We gained an understanding of how beekeepers feel about the future outlook of their practices. A full list of questions is provided in appendices C and D.

We interviewed scientists to corroborate and supplement the information we received from beekeepers. Scientists from Dr. Yashwant Singh Parmar University of Horticulture & Forestry (Dr. YSP University) provided us with climate data to corroborate the seasonal data we received from beekeepers. An entomologist to provide supplemental information about bee and pest behavior. An apicultural expert provided information about changes in beekeeping practices in Himachal Pradesh over time.

Objective 2: Analyze and Present Beekeeper's Adaptations and Challenges

We compared the calendars we created from each interview with one another and observed trends based on elevation and location. We analyzed the frequency with which beekeepers reported changes and their perceived causes of these changes. The calendars were entered into the digital calendar tool, and we analyzed the effectiveness of the existing calendar tool at representing beekeepers' schedules.

In addition to the calendar data, we analyzed the other challenges reported by beekeepers, their perceived causes of these challenges, and the frequency with which these challenges were reported. From this, we concluded the challenges beekeepers are most concerned about.

Objective 3: Evaluate Perceptions of Seasonality and Change in Response to Climate Change

We interviewed beekeepers in villages at different altitudes in Himachal Pradesh. We observed the quantity of hives each beekeeper had and their emotional responses when discussing climate related issues. We used information from interviews to create a visual representation of the calendar year as described by the beekeepers in the present and as described by the beekeepers' recollection of 10 years in the past.

We analyzed the frequency with which beekeepers in different locations experienced changes in seasonal patterns. We recorded the changes they observed (i.e. different flowering times of important flora, increased pest infestation, deforestation, etc.) and determined which factors were most prevalent in each given region.

Chapter 4: Results and Discussion

We interviewed eight beekeepers, as shown in Table 2 and Appendix A. Through these interviews, we gained information about changes in beekeeping practices with respect to the following variables: location and environment, pests and colony health, beekeeping methods, human impacts on the environment, and calendars and timing. Beekeepers reported decreased bee population, honey production, floral availability, changes in weather, and concern about pesticides.

Table 2: Guide to beekeepers that were interviewed.

Location	Elevation (m)	Bee Species	Hive Type	Method
Chamah	1000	*A. mellifera, A. cerana*	Wall, Box	Stationary
Shegli	1400	*A. cerana*	Wall	Stationary
Shegli	1400	Unspecified native species	Wall	Stationary
Gumma	1189	*A. cerana*	Box	Stationary
Naggar	1800	*A. cerana*	Log, Mud, Box	Stationary
Bajaura	2780	*A. cerana*	Wall	Stationary
Bajaura	60-2780	*A. mellifera*	Box	Migratory
Kullu	100-4270	*A. mellifera*	Box	Migratory

Interview Results

Beekeepers reported a variety of factors that influence their productivity. The factors and extent to which the beekeepers notice a given factor was impacted by location and beekeeping method.

Location and Environment

Six out of eight beekeepers reported experiencing warmer temperatures, weather phenomena such as drought, heavy rains, and more variable weather were also reported (Figure 8). All but one beekeeper reported either shifts in flower's blooming times (Figure 9) or decreased nectar production (Appendix B).

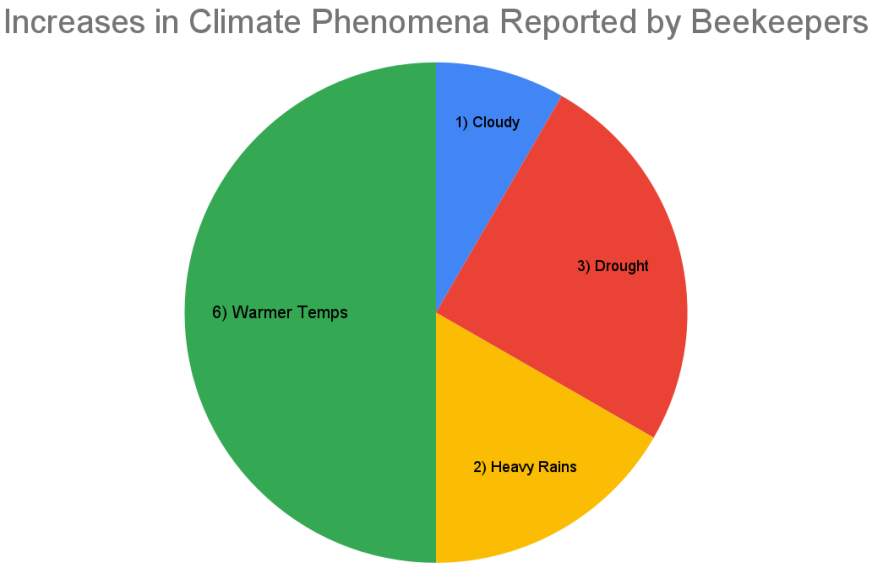

Figure 8: Increases in climate phenomena reported by beekeepers (N = 8). Some beekeepers reported more than one factor.

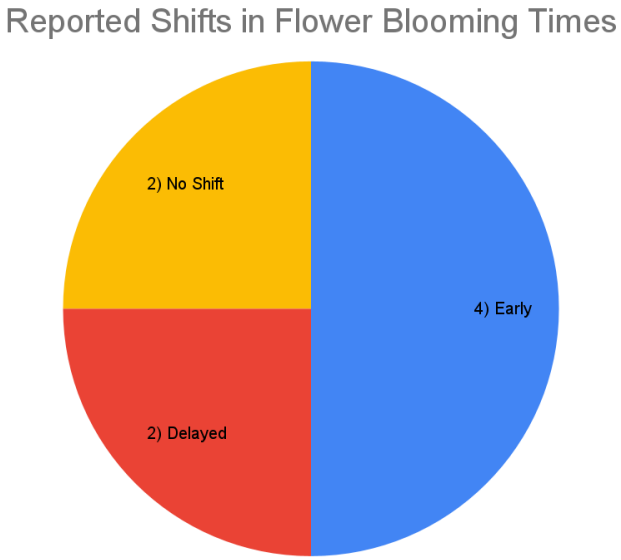

Figure 9: Shifts in flowering times reported by beekeepers (N = 8).

Beekeepers at lower altitudes (less than 2000m) reported less impacts from climate change than those at higher altitudes (greater than 2000m). Beekeepers in higher altitude villages reported more hardships and more adaptations. For example, higher altitude beekeepers reported greater impact by pesticide use and temperature change and reported more changes to their techniques.

The Italian honey bee, *Apis mellifera*, is more temperature sensitive than the indigenous *Apis cerana* (R. K. Daroch, personal communication, April 2, 2024). Some of the beekeepers interviewed reported adding additional wood to box hives to keep them cool, or adding insulation and box hives with more frames in order to cope with increasing temperatures. Additionally, *A. mellifera* cannot withstand temperatures below 12 degrees celsius, so *A. mellifera* beekeepers in the high hills must migrate 4-5 months of the year to warmer regions (R. K. Daroch, personal communication, April 2, 2024).

Pests and Colony Health

Of the eight beekeepers interviewed, six reported decreased bee population or brood size. One stationary beekeeper reported that his bee population had decreased by 60% over the past 20 years (beekeeper 3, personal communication, March 20, 2024). Four of the beekeepers directly cited pesticides as a reason for their bee populations decreasing (Appendix B).

Of a total of six stationary beekeepers, two reported an increase in pests. One reported an increase in wax moths, and the other an increase in brood mites. A decreased brood size provides more space in the hive for wax moths, and a weaker colony is more vulnerable to pests in general. One migratory beekeeper stated that his pest problems have decreased as he has learned about preventative maintenance. Two of the six stationary beekeepers also reported an increase in diseases in their bees. One beekeeper reported that his bee's decreased brood size was caused by pesticides and the transfer of disease between *A. cerana* and *A. mellifera*. Another beekeeper expressed concern about the two bee species fighting. Scientists were unable to corroborate either of these concerns. The other beekeeper gave no explanation for the increase in disease.

Of the six stationary beekeepers we interviewed, 83% reported a decrease in their honey production. The highest elevation stationary beekeeper reported that last year there was nearly no honey production from local bees. Figure 10 shows the changes in honey production reported by the stationary beekeepers and the reasons they attributed to these changes.

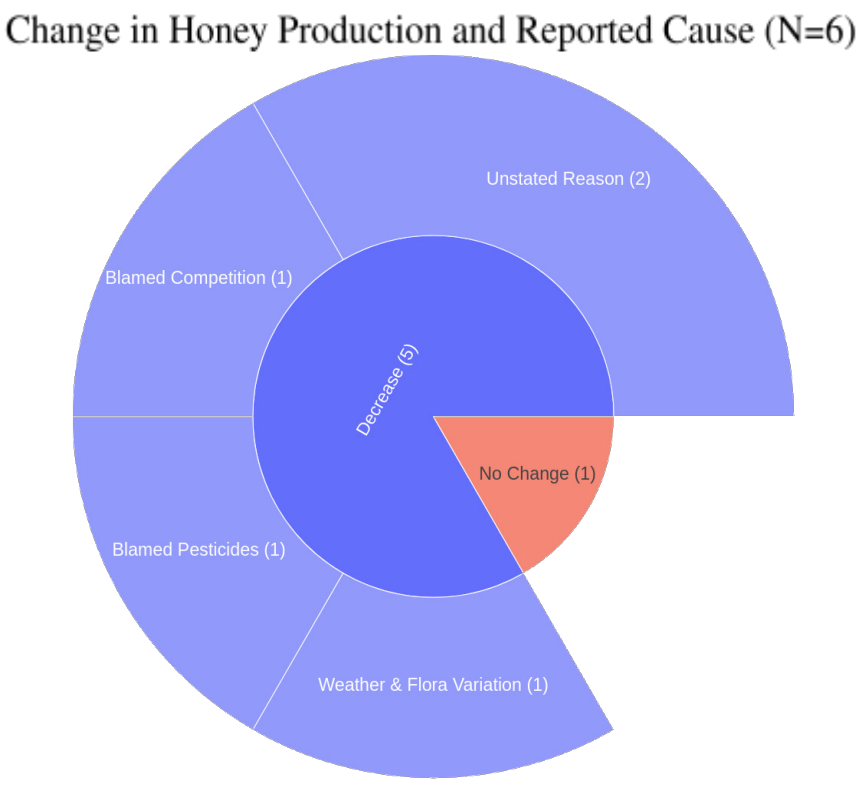

Figure 10: Change in honey production and reported cause (N=6) The inner circle represents the number of stationary beekeepers that reported either a decrease in their honey production or no change (N = 6). The outer circle represents the reasons stationary beekeepers believed their honey production was decreasing.

Beekeeping Methods

Some beekeepers reported changing their techniques after attending training from either local agricultural universities or other beekeepers. Two out of six stationary beekeepers stopped the use of chemical pesticides in their hives after learning about the damaging effects these chemicals had on bees. One beekeeper reported that he began supplementing his hives with food after learning to do so.

Several beekeepers reported returning to indigenous methods. One beekeeper reported that he used to use box hives but switched to wall hives because they provide better temperature regulation. Another beekeeper was currently using box hives but was experimenting with log hives for the same reason. This beekeeper also reported that honey production was higher in the past when indigenous methods were used.

Other beekeepers reported changing their methods for their livelihoods. Two stationary beekeepers reported having tried to keep *A. mellifera* but stopped because it was too labor intensive. Two stationary beekeepers reported using more "scientific" tools in order to work with *A. mellifera* and increase the quality of honey production.

Migratory beekeeping also has its own set of adaptations to reduce harm from pesticides and maximize honey production. Some migratory beekeepers migrate together and support each other along their route (beekeeper 8, personal communication, April 21, 2024). Beekeepers monitor their hives regularly and observe when there is a lack of food in their hives, indicating that it is time to move to their next location. Before traveling, the beekeeper learns what flora is available where in order to decide their next location. Technical departments define routes and flowering times that are communicated to migratory beekeepers (H. K. Sharma, personal communication, April 17, 2024). Migratory beekeepers rely on both wild flora, like wild thyme in Lahaul, and crops, such as apples in Kullu. When migrating to areas where the main flora sources are crops, beekeepers increase the risk of exposing their colonies to pesticides. Some migratory beekeepers report changing their routes to avoid intensive pesticide use, and some reported pesticides as a concern specific to the plains regions in their route.

Indigenous methods of beekeeping with *A. cerana* in wall, mud, or log hives are less involved than scientific methods using box hives and *A. mellifera*. *A. mellifera* are more high maintenance as they require more flowers and space than *A. cerana*, and need to migrate if the region gets too cold ((H. K. Sharma, personal communication, April 17, 2024)). Traditional hives, particularly wall hives, have better temperature regulation. Beekeepers using wooden box hives reported needing to use insulation or ventilation to manage temperatures in the hive.

Indigenous hive types require the least maintenance. Beekeepers harvest honey from indigenous wall or log hives one to two times a year. According to beekeepers, wall hives do not require constant surveillance for pests. Humidity during monsoon season is opportune for wax moths, so during monsoon season beekeepers will check for pests and treat their hives as needed. Stationary box hives also require honey to be harvested up to two times a year, but require more constant surveillance for pests. During the winter dearth season, beekeepers check their stationary hives to know when the colony needs supplementary food. Migratory box hives need to be checked daily for food available in the hive and for cleaning. Honey is harvested from migratory box hives every seven to ten days.

Human Impacts on the Environment

Climate related factors were not the only things causing changes observed by the beekeepers. As shown in Figure 11, Five beekeepers observed decreased flora availability, one of whom also stated that he observed decreased flora in every location of his migration route (Appendix B).

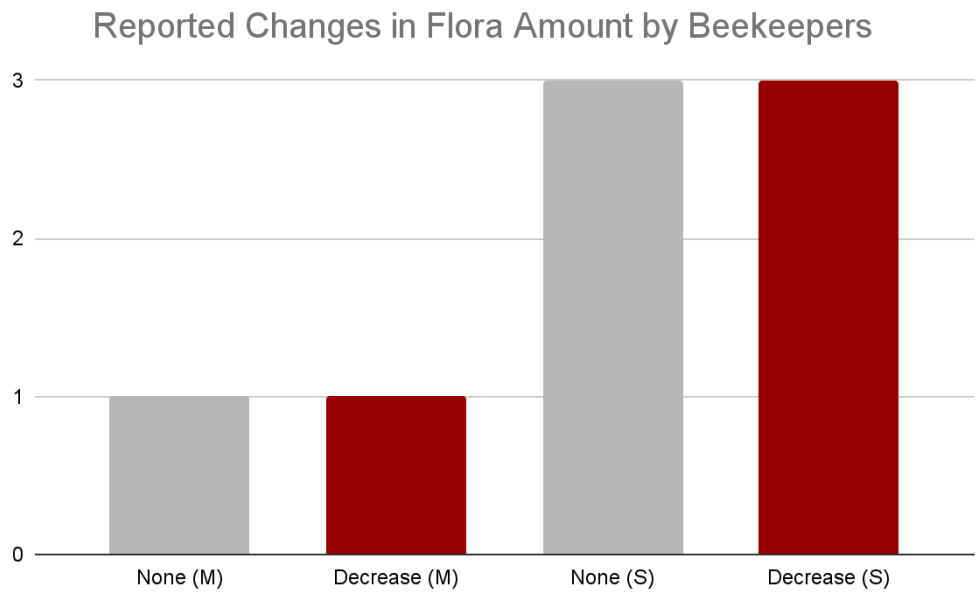

Figure 11: Reported changes in flora amount by beekeepers (N = 8). (S) indicates stationary, (M) indicates migratory.

The reasons cited by beekeepers for this decreased flora availability were attributed more to human activities than climate related factors (Figure 12). The only climate related factor reported was warmer temperatures, and it was only reported by 1 beekeeper. Three beekeepers attributed decreasing flora availability to agriculture (monoculture and greater land use), Two to deforestation for road building and construction, two to pesticides and one to competition from increased number of beekeepers in their area. Some beekeepers reported several reasons for the decrease.

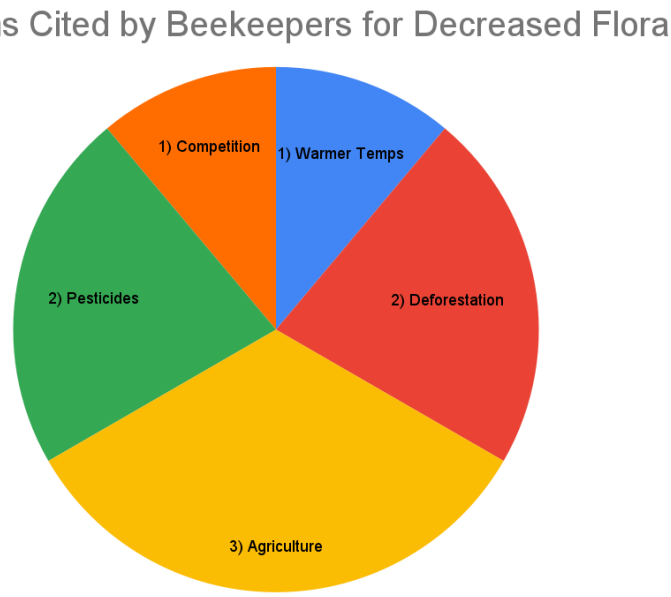

Figure 12: Reasons cited by beekeepers for decreased flora availability (N = 8). Some beekeepers reported more than one reason for decreased flora.

In terms of threats to their colonies and honey production, pesticide use was the most consistent concern among the beekeepers we interviewed. Five stationary and two migratory beekeepers reported pesticide use as a problem (Figure 13). Two beekeepers in Shegli village expressed this issue with anger and frustration. Two beekeepers stated that pesticide use was decreasing flora in the area, and five beekeepers stated that pesticides kill bees and/or reduce brood size (Appendix A).

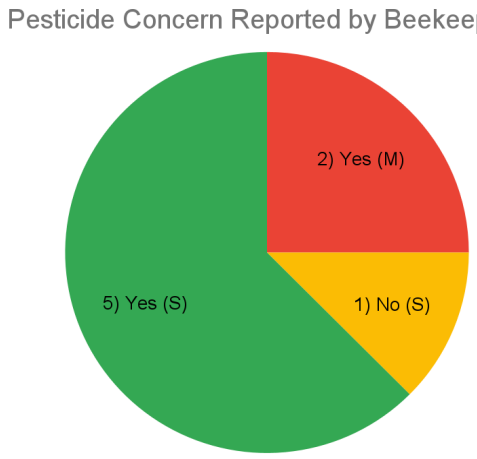

Figure 13: Pesticide concern reported by beekeepers (N = 8). (S) indicates stationary, (M) indicates migratory.

Himachal Pradesh has undergone many changes as a result of urbanization that directly impacts apiculture. Urbanization has led to the reduction of wild flora through deforestation for road building and other construction. Additionally, new construction techniques conflict with indigenous beekeeping methods. Concrete houses do not allow for wall hives to be constructed in the walls of newer homes, which decreases the population of wild *A. cerana* that form colonies for beekeepers. The development of large scale agriculture has introduced more monoculture orchards.

As large scale agriculture continues to grow, pesticide use increases as well. Pesticides can have direct and indirect impacts on bee health. Bees can be exposed to pesticides directly if pesticides are sprayed during foraging or sprayed onto flora that bees forage on. This adversely affects foraging behavior and colony health. Additionally, many chemical pesticides are harmful to plant life and can therefore damage and reduce the flora available in the region for foraging.

Beekeeper Perceptions of Seasons

Beekeepers divide the year based on established seasons, bee activity, and plant life. When asked about the seasons of the year, beekeepers often responded with well-established existing seasons: spring, summer, monsoon, autumn, and winter. Some beekeepers seemed to use spring and summer interchangeably, and autumn was rarely referred to. In some interviews, we had to directly ask beekeepers when a given season was during the year. This influenced the freedom of the beekeeper to respond with their own ideas of how the calendar year is divided. Following the end of monsoon season, there are a few months before winter begins. One beekeeper referred to this as autumn, but the beekeepers we interviewed did not have a consistent name for this period of time. For the purpose of this analysis, we will refer to this period of time as “spring-soon.”

We found that *A. cerena* are active and forage during the spring/summer and the “spring-soon” months and generally hibernate during the winter. These seasons are shown in Figure 14. Some beekeepers reported that bees will come out on sunny days in the winter, but they do not forage. Heavy rains decrease bee activity during monsoon seasons, but in certain locations, bees are not entirely inactive during monsoon season. Beekeepers in Shegli, Gumma, and Naggar reported that their bees are still active in Monsoon season, while a beekeeper in Chamah said that his bees would hibernate during the monsoon season. The beekeepers in Gumma and Naggar additionally reported that the bees became more active after monsoon season ended, before hibernating during the winter.

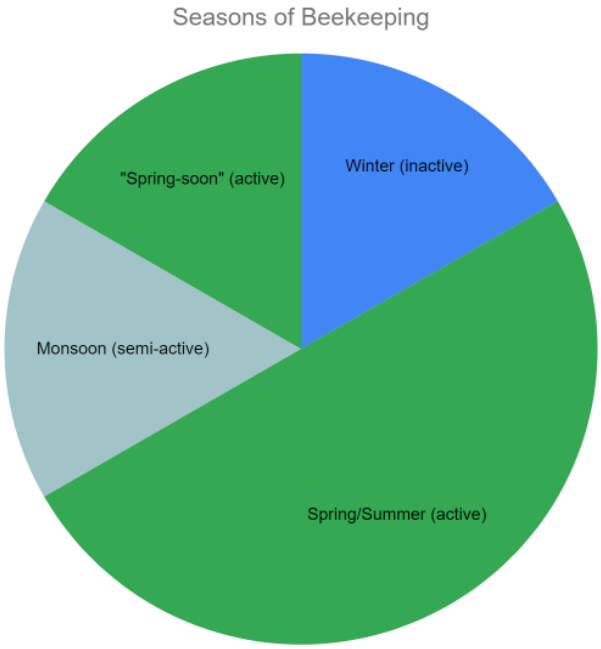

Figure 14: Dearth periods for *A. cerana* are represented in dark blue, and active periods are represented in green. Light blue indicates deceased foraging compared to active seasons but not complete inactivity.

Beekeepers talked about their activities and beekeeping in reference to the basic seasons. For example, they reported that bees forage during the spring or that they dust sulfur for wax moths during monsoon season. Stationary beekeepers used “active season” and “off season” to describe the parts of the year when their bees were foraging and hibernating, respectively. Migratory beekeepers did not use these phrases because their colonies are always active. Stationary beekeepers using indigenous methods often open their hives only four times a year, so beekeeping is not influential enough on the year to create names for seasons based on beekeeping activities.

Migratory beekeepers defined some of their year based on important plants. Certain locations in their migratory routes were not defined by a single plant or crop. Others were strictly associated with a certain flora source. For example, one beekeeper reported migrating to Lahaul for wild thyme, Haryana for eucalyptus, Rajasthan for mustard, and Kullu for apple.

Calendars and Timing

When interviewing beekeepers, we collected the following information about each season they reported: time and length, bee activity, beekeeper activity, important flora available for bees, indications of start and end, and pests and pathogens. We collected this information for the present and 10 years ago. The information was arranged in a linear calendar (Appendix D) to visually demonstrate the differences in schedules between beekeepers in different locations and between a given beekeeper's past and present schedule. A sample calendar is shown in Figures 15 and 16. Several beekeepers observed changes in flowering times of important nectar producing flora, changes in foraging activity, increased pests, decreased bee populations, decreased flora availability and decreased honey production. We observed different responses based on the interviewee's altitude and beekeeping method.

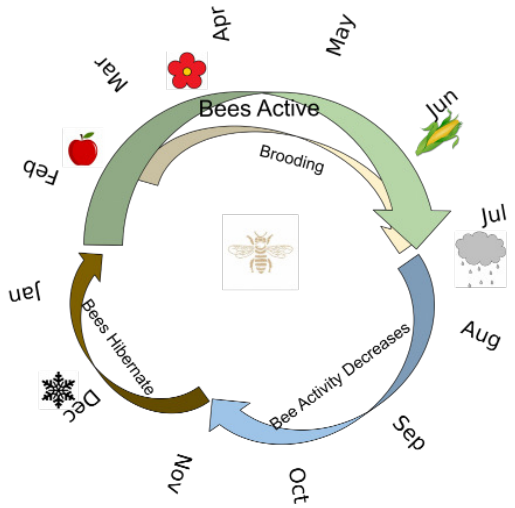

Figure 15: The current calendar of beekeeper 3 (1400m). The calendar shows the seasons, bees activities, beekeepers activities, and flora throughout the year.

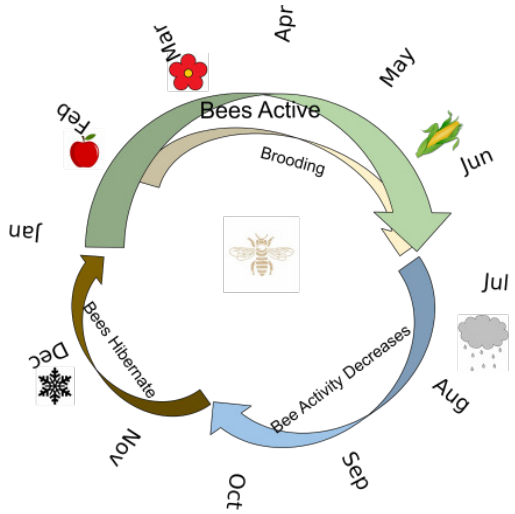

Figure 16: The past calendar of beekeeper 3 (1400m) from 10 years ago. There is a ~15 day early shift from the calendar in Figure 15.

Some beekeepers reported that seasons started and/or ended at different times than they used to. Beekeepers reported a change of about 10-20 days (Appendix B). One migratory beekeeper reported that his entire yearly calendar was shifted 10 days later compared to when he began beekeeping, while another reported that times for migration vary by ten days earlier or later but that this has been consistent for the past ten years. Beekeepers reported more changes in

factors like pests and pathogens, floral availability, and methods than they did changes in seasonal timing.

In addition to entire shifts in seasons, some beekeepers reported that flowers bloom at different times of the year than they used to. One beekeeper reported rhododendron as an important flower to indicate the beginning of spring and that rhododendron was blooming almost a month later now than it was ten years ago.

Analysis

From the data collected in interviews, we found several broad trends reported by multiple beekeepers. Some trends deal with the impacts of the climate and the environment, while others deal with the changing environmental context due to human factors, such as changes in farming practices and construction. Finally, we observed that change in the practice of beekeeping is also driven by the beekeepers themselves, adopting new methods to increase their own productivity and to cope with changes in beekeeping conditions.

Temperature Change Requires Management

The native Indian honey bee, *A. cerana*, is well adapted to the cold temperatures experienced in the high hills of Himachal Pradesh (H. K. Sharma, personal communication, April 17, 2024). Beekeepers who keep *A. cerana* are thus able to practice stationary beekeeping. They may use fixed mud hives, log hives, or wall hives. Stationary beekeepers interviewed reported that these structures are able to better withstand fluctuating temperatures than wooden box hives. No beekeepers reported making changes to these indigenous hives (wall hives, log hives, and mud hives) in order to adapt to increasing temperatures. *A. cerana* can also be kept in wooden box hives, but indigenous hive types have been reported to be more effective for *A. cerana* especially.

Adaptations to the wooden box hives to deal with fluctuating temperatures include providing additional ventilation, and packing the boxes with insulation when it's too cold (R. K. Daroch, personal communication, April 2, 2024). Some beekeepers reported spraying their box hives with water in order to keep cool. Others reported switching from eight frame box hives to ten frame box hives with a feeder because the larger hive is better suited to deal with temperature variations.

Impacts of Temperature & Rainfall Variability Caused by Climate Change

Increasing average global temperatures can directly impact the timing of seasons and activities of bees and consequently beekeepers. Warmer winters cause the flora that indicates the beginning of spring to bloom earlier. Increased temperatures can also provide better conditions for pests to thrive in bee colonies. Higher altitude environments are more sensitive to these increasing temperatures, thus beekeepers at higher altitudes are experiencing new hardships before beekeepers at lower altitudes, and to a greater extent. Other climate change factors have had a more direct impact on beekeepers regardless of elevation.

Changes in rainfall directly impact the health and availability of the flora that bees rely on. Flowers life cycles, especially nectar production, are heavily impacted by soil moisture (H. K. Sharma, personal communication, April 17, 2024). Warmer temperatures and changing rainfall patterns impact soil moisture, which in turn impact when a plant flowers and how much nectar it produces. Additionally, beekeepers have reported flora drying up at different times of year than they used to, suggesting that dry periods are becoming drier. Migratory beekeepers reported decreased nectar production even in the low elevations of the plains in Haryana, Rajasthan, and Uttar Pradesh.

Four stationary beekeepers reported that wax moths are a threat during a specific season, three of which reported wax moths were especially problematic during monsoon season and one of reported winter. Wax moths thrive on the humidity provided by heavy rain during monsoon season, heavier periods of rain can allow the wax moths to thrive.

Human-Driven Environmental Change Harms Bees

Honey production in the high hills of Himachal Pradesh is decreasing as more of the region is used for intensive agriculture and is otherwise developed (H. K. Sharma, personal communication, April 17, 2024). Some beekeepers reported up to a 50% decrease in their honey production over the last 10 years.

Regardless of altitude or method, human activity, agriculture, and climate change are causing a decrease in nectar producing flora. The lack of wild food for bees has led many beekeepers to supplement their bees with other food sources like bee pollen, sugar water, or sugar cane extract.

Decreasing floral variation and density is detrimental to bee foraging behavior. Areas that are used for intensive agriculture are decreasingly viable for beekeeping (H. K. Sharma, personal communication, April 17, 2024). Monoculture, the use of land to grow a single crop, is increasing, often in orchards resulting in areas which only flower once a year. As a result, wild flora in the area is reduced, and there are fewer pollen and nectar sources for surrounding bee colonies. Urbanization also strips the region of its floral diversity, as deforestation for road building, and forest fires sparked by humans reduce floral density in the area.

Pesticide Use Has a Major Impact on Beekeeping

Increasing average temperatures as a result of climate change leads to increased pest populations, which has resulted in increased pesticide use in agricultural applications. Pesticide and insecticide resistance leads to the use of more and new chemicals. Pesticide use decreases flora availability and negatively impacts bee and brood populations (R. K. Daroch, personal communication, April 2, 2024).

Beekeepers reported the different problems caused by pesticide use (Figure 17). Two beekeepers stated that pesticide use decreases flora. Three beekeepers stated that pesticides decrease brood size. One beekeeper referred to this decrease in brood population as the reason for increased wax moths. Lastly, five beekeepers stated pesticides are killing their bee population, and one beekeeper stated that this is responsible for decreased honey production.

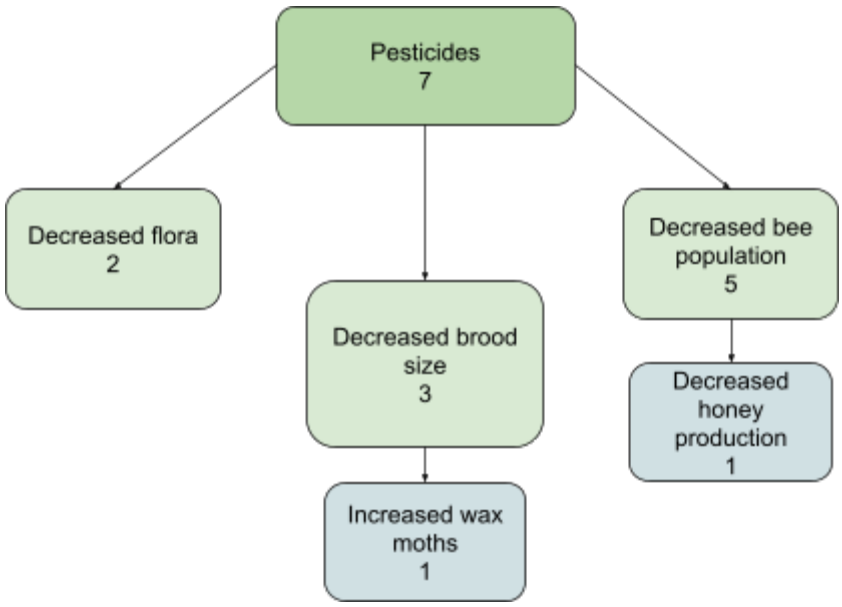

Figure 17: The number of beekeepers that reported pesticides as being a problem, and their effects on other issues (N = 8). Some beekeepers reported several problems resulting from pesticides.

Education and Training Helps Beekeepers

Some beekeepers reported not having supplemented their hives with food until they were taught about the practice in trainings, emphasizing the importance of education in providing beekeepers with necessary resources to cope with climate change.

Increased apicultural education has allowed beekeepers to make other technical adaptations to mitigate losses due to climate change. Information about pesticides informs farmers when to spray pesticides to avoid exposure of the bees to pesticides. For example, spraying during the pink bud phase of apple growth, before bee foraging begins (R. K. Daroch, personal communication, April 2, 2024), or at night when bees are inactive (beekeeper 7, personal communication, April 21, 2024) are two options to decrease bee exposure to pesticides. Natural farming uses crops that are naturally pest resistant instead of the commercial crop species to entirely avoid the need for pesticides. Some beekeepers have opted for cow urine in place of chemical pesticides on their hives (beekeeper 5, personal communication, March 29, 2024; R. K. Daroch, personal communication, April 2, 2024).

Industrial Beekeeping Methods are More Productive

By enabling greater access to the colonies, industrial beekeeping methods enable beekeepers to increase honey production and reduce effort required for certain tasks, such as harvesting honey. They can also be more easily modified for changing environmental conditions by changing the insulation or other aspects of the hive to improve temperature regulation, though unlike indigenous methods, they are more likely to require this modification. Indigenous hive types provide very little access to the colony and do not feature removable frames, which complicates honey extraction, and makes it difficult for beekeepers to check for pests on the frame and remove them if they exist. Beekeepers using industrial methods (box hives and other tools) reported a significant variety of methods to control pests and monitor their hives (beekeeper 4, personal communication, March 27, 2024; beekeeper 5, personal communication, March 29, 2024), while beekeepers using indigenous methods (primarily wall hives) could not do so, due to the fixed location of the hives and the difficulty involved in accessing the contents. Adopting migratory beekeeping also substantially increases honey production (Brar et al., 2018), but requires substantially more commitment.

Migratory Beekeeping is an Extreme Environmental Adaptation

As stationary beekeeping is threatened by change, one of the main adaptation strategies for beekeepers has been to switch away from stationary beekeeping with *A. cerana* to migratory beekeeping with *A. mellifera,* which also boosts the income of beekeepers. As supplementing hives with sugar or other food is expensive and lowers honey quality, the only option for beekeepers faced with reduced floral availability is to move their hives to regions where flora is more readily available. As honey production in Himachal Pradesh has decreased, honey production in the plains belt has increased as an interest in commercial beekeeping, and with it migratory beekeeping increases among Himachali beekeepers (H. K. Sharma, personal communication, April 17, 2024).

Migratory beekeeping requires the most hands-on maintenance of the beekeeping methods. Indigenous beekeeping methods with *A. cerana* require little care. Stationary beekeeping with *A. mellifera* is more sensitive to climate variability and pests and is used predominantly for profit, so it requires more maintenance. Migratory beekeeping requires the most maintenance because it utilizes *A. mellifera* colonies that are active year round. Migratory beekeepers reported checking their hives daily to know when to extract honey. Migration also requires that beekeepers continue moving to warm regions with floral availability to avoid dearth periods during monsoon and winter seasons, so migratory beekeepers are unable to report on the changes in seasons in one given location. However, the constant maintenance that migration requires allows migratory beekeepers to be the most in tune with the health of their hives in relation to external conditions.

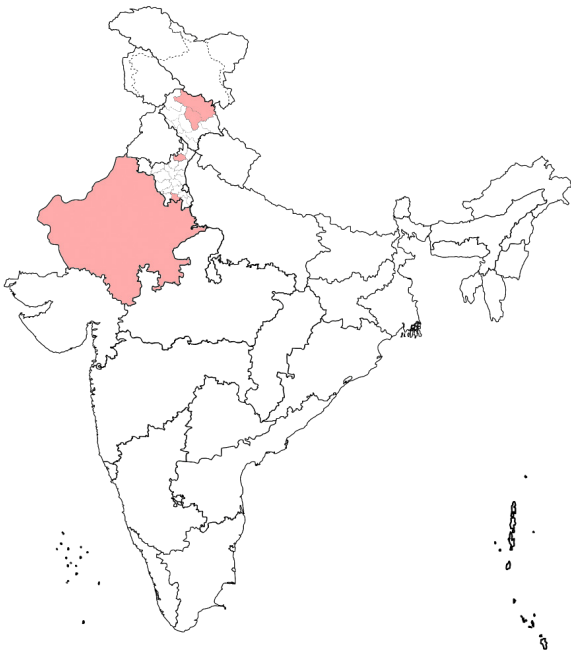

Figure 18: Map of migratory route of beekeeper 6. Their route goes from Kullu to Lahaul & Spiti in Himachal Pradesh, to Ambala in Haryana, to Rajasthan, to Rewari in Haryana.

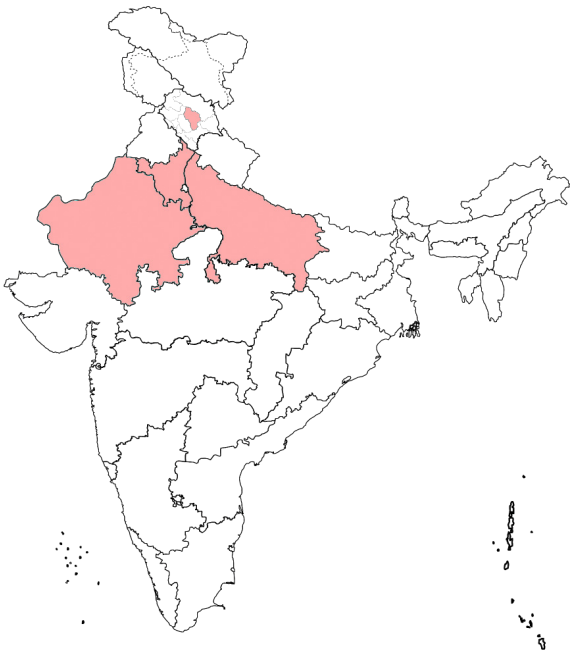

Figure 19: Map of migratory route of beekeeper 8. Their route goes from Kullu in Himachal Pradesh, to Haryana, to Uttar Pradesh, to Rajasthan, to Haryana.

Migratory beekeepers are dependent on reliable transportation in order to bring their bees to the most viable flora sources. As shown in Figures 18 and 19, migration involves multiple moves a year, frequently between states. Some beekeepers specified the village or region to which they travel, while others only named the state. The migratory beekeepers we spoke to reported the process of moving the bees as the most challenging part of their migration, and poor road conditions would only serve to worsen that. Although road building in Himachal Pradesh contributes to deforestation of local flora and increases landslide risk, migratory beekeepers rely on roadways for their productivity.

Discussion

Migratory beekeeping can create increased competition as beekeepers from a widespread area all migrate to a concentrated region. Migratory beekeeping in other parts of the world has led to depleted resources and decreased production in the region being migrated to, so it is possible that migratory beekeeping from Himachal Pradesh can deplete resources in the plains (Gajardo-Rojas et al., 2022). It is possible that as adoption of migratory beekeeping in Himachal Pradesh increases to increase local honey production, honey production in the plains will eventually decrease due to overuse of resources in the region.

As agriculture and urban development continue throughout Himachal Pradesh, we expect flora availability to continue to decrease. Road-building and other urbanization efforts reduce the area available for wild flowers, while the increasing practice of monoculture and increased use of land for agriculture hurt floral diversity. Additionally, commercial agriculture will continue using chemical pesticides and fertilizers, and their use will increase as insect resistance leads to the need for new pesticides.

Comparing CALENDARS Project Research in Different Locations

The CALENDARS project has observed beekeeping in several locations around the world. Prior to our research in Himachal Pradesh, two research projects were completed in New Zealand and Hong Kong (Arroyas et al., 2024; Ehmer et al., 2024). We compared the key findings from these two projects with our data (Table 3). Each project sought to answer the following three questions:

1. How have beekeeping practices and technological tools that support beekeeping changed?
2. What is the future outlook for beekeeping as described now by beekeepers?
3. What climate change indicators and vulnerabilities are reported?

Table 3: The CALENDARS project Himachal Pradesh, India, New Zealand, and Hong Kong.

	Himachal Pradesh	**New Zealand**	**Hong Kong**
Changes in tools and practices	• Industrial methods and beekeeping for profit • Indigenous practices for recreation	• Supplemental feeding • Beekeeping more technical and scientific • Sprinklers	• Urban apiaries
Future outlook of beekeeping	• More education for beekeepers • Urbanization decreases flora • Pesticides	• Regulations have made beekeeping less profitable • Varroa mites	• Concerned about current environmental challenges worsening
Climate change indicators and vulnerabilities	• Increased temperature • Changes in rainfall • Decreased nectar production	• Increased temperatures • Increased rainfall • Severe storms	• Weather fluctuations • Migration of native flora to higher altitudes

How have beekeeping practices and technological tools that support beekeeping changed?

Beekeepers in Himachal Pradesh and New Zealand reported that they recently began supplementing their hives with additional food in response to changes in floral availability. In Himachal Pradesh, beekeepers are supplementing their hives with food because flora sources in the area have decreased, there is more competition for flora sources, or to increase production. In New Zealand, plants are flowering during the winter due to increased temperatures, so bees are now active during the winter, and beekeepers have to provide supplementary food to compensate for this. Additionally, sprinkler irrigation systems in New Zealand are rinsing the nectar off of plants, which likely creates more need for supplementation.

Both Himachal Pradesh and New Zealand have observed beekeeping become more technical and scientific. Himachali beekeepers often refer to new technologies like box hives as "scientific." Beekeepers in New Zealand reported that beekeeping has become more of a science when it used to be an art. As beekeeping for profit in Himachal Pradesh becomes more reliant on science, we expect the emergence of beekeeping for recreation to grow. Some beekeepers in Himachal Pradesh are using migratory beekeeping for profit and stationary beekeeping for their own use.

Hong Kong has urban centers unlike the majority rural population of Himachal Pradesh. To increase pollinator populations in growing urban centers, Hong Kong has seen an increase in urban apiaries, which expose bees to more contaminants and high temperatures while also helping pollinate in urban areas.

What is the future outlook for beekeeping as described now by beekeepers?

Beekeepers in Himachal Pradesh and New Zealand are reliant on their community for information. New Zealand has more structured organizations for beekeeping than Himachal Pradesh. Universities, like Dr. YSP University, in Himachal Pradesh have been increasing the outreach of their training programs to help educate more beekeepers within the past decade. Government organizations, like the Khadi Village Industries Commission, have sought to prompt beekeeping for profit throughout the past century. These efforts have been disorganized, and beekeeping for profit using modern methods is just gaining momentum in the past few decades. Individual beekeeping trainers in Himachal Pradesh have played an important role in sharing new information about beekeeping techniques. New Zealand's beekeeping association has monthly meetings that allow for beekeepers to share information with more ease.

Government support in Himachal Pradesh has generally worked in the favor of increasing productivity, but this has not always been the case in New Zealand. Government regulations on Mānuka honey have made beekeeping less profitable, so much so that some beekeepers have left the practice.

Beekeepers in Himachal Pradesh, New Zealand, and Hong Kong are concerned about various factors adversely affecting their beekeeping. Beekeepers in Himachal Pradesh most frequently expressed pesticides as a concern. One beekeeper stated he may stop beekeeping should pesticide use worsen. Beekeepers in New Zealand are particularly threatened by Varroa mite, which can be expected to worsen as global temperatures continue to increase. Lastly,

beekeepers in Hong Kong expressed concerns about current environmental challenges worsening.

What climate change indicators and vulnerabilities are reported?

Beekeepers in these three regions are impacted by similar changes in the climate. Himachali beekeepers are affected by increased temperatures and rainfall variability, which decrease nectar production in plants. Increased global temperatures have increased the impact of Varroa mites for beekeepers in New Zealand. Additionally, beekeepers in New Zealand are affected by increased rainfall and severe storms. Beekeepers in Hong Kong are experiencing weather fluctuations and observing the migration of native flora to higher altitudes as a result of increasing temperatures.

Goal: Evaluate the extent to which beekeeping schedules in Himachal Pradesh are affected by climate change.

Our project executed the following three objectives in order to achieve the aforementioned goal:

1. Understanding Bee and Beekeeper Activity in Himachal Pradesh
2. Analyze and Present Beekeeper's Adaptations and Challenges
3. Evaluate Perceptions of Seasonality and Change in Response to Climate Change

Understanding Bee and Beekeeper Activity in Himachal Pradesh

The native *A. cerana* bee is active during warm, sunny months and inactive during colder, rainy months. The imported *A. mellifera* bee is also inactive during cold, rainy months but can be active all year if migrated. Beekeeper activity varies greatly based on the species of bee and the method. Generally, methods with *A. cerana* are less labor intensive.

Analyze and Present Beekeeper's Adaptations and Challenges

Beekeepers are using new technology in order to increase production. Newer technologies and methods are more sensitive to changes in the environment and therefore require adaptations to cope with adversities like temperature variation and pests. However, indigenous methods are not being adapted to cope with climate change.

Evaluate Perceptions of Seasonality and Change in Response to Climate Change

Beekeepers participating in methods that require more maintenance are more aware of changes in the environment. Similarly, beekeepers at higher altitudes are more aware of changes in the climate. The ways in which beekeepers perceive changes in the climate and seasons is dependent on their methods and location.

Chapter 5: Conclusions

Indigenous Methods of Beekeeping are More Resilient to Climate Change

The native *A. cerana* is better adapted to the local climate than *A. mellifera*. *A. cerana* requires fewer resources, like flora and space, and can cope with colder temperatures. The indigenous hive types used to keep stationary colonies of *A. cerana*, like wall hives, have better temperature regulation than box hives. The mud walls of wall hives allow the hive to remain cool during hot seasons. In contrast, *A. mellifera* needs to be migrated to warmer locations when the temperature is below 12 degrees Celsius, and box hives need to be insulated during cool seasons and ventilated during hot seasons. *A. cerana* colonies require less maintenance by beekeepers to cope with temperature variations.

As a result of their natural adaptations to the region, indigenous beekeeping methods require less maintenance. Stationary wall, log, or mud hives of *A. cerana* are less susceptible to pests than box hives of *A. mellifera*. Box hives need to be monitored frequently for cleaning and honey harvesting. For example, migratory beekeepers check their box hives daily to determine when it is time to travel. Similarly, box hives require frequent cleaning. Some beekeepers replace the plastic in their box hives weekly, shown in Figure 20. Some beekeepers have returned to indigenous methods after attempting to keep *A. mellifera* because of lower maintenance requirements.

Figure 20: Plastic bag in box hive used for migration of *A. mellifera*.

Although indigenous beekeeping methods are better adjusted to the climate of Himachal Pradesh, they cannot keep up with the demand for productivity, especially as the climate continues to change. *A. cerana* requires less flora than *A. mellifera* in order to survive and produce honey. When flora sources are lacking, *A. cerana* colonies will produce less honey, but *A. mellifera* colonies will die (H. K. Sharma, personal communication, April 17, 2024). Although *A. cerana* can survive this environmental change better than *A. mellifera*, beekeepers cannot rely on *A. cerana* to increase their profit and productivity as flora sources continue to decrease.

There is an Increase in Stationary and Migratory Beekeeping for Profit

Interest in beekeeping in Himachal Pradesh is increasing, and with it, beekeeping for profit is becoming more popular. In order to increase productivity when the climate is changing and competition is increasing, beekeepers have to deviate from indigenous methods. Beekeeping in Himachal Pradesh has become increasingly technical as beekeepers have made adaptations to their methods to cope with changes in the environment and industrial methods have grown in popularity.

Beekeeping in Himachal Pradesh has become more dependent on scientific knowledge from local universities in order to implement new technologies like box hives and migration. The sharing of information among beekeepers is increasing. University and village trainings provide opportunities for beekeepers to gather and learn together. Private beekeeping trainers share their knowledge and practices while creating a network of the beekeepers they train. The increase in beekeeping for profit creates a new need to share knowledge efficiently among beekeepers in order to mitigate new complications.

Threats to Himachali Beekeeping are Predominantly Urbanization and Agriculture

Beekeepers reported fewer climate change factors than anticipated. Climate change was not the main concern among the beekeepers we interviewed. The beekeepers that were concerned about climate change and weather variability tended to be those at higher altitudes. However, beekeepers at all altitudes were more concerned about urbanization and agriculture. Beekeepers expressed urbanization and agriculture as main threats to their practices.

Urbanization leads to deforestation for road building and other construction, which decreases flora in a given area. However, apiculture has a much stronger relationship with agriculture. Agriculture uses limited land for a single crop, decreasing flora for bees, while exposing bees to harmful chemicals. These factors are the greatest obstructions to beekeepers' productivity, so much so that some beekeepers have expressed their desire to stop beekeeping should pesticide use increase. These factors are interconnected, the growth of agriculture in Himachal Pradesh will be accompanied by further urbanization.

Migratory beekeepers have unique concerns about urbanization. Poor road conditions are one of the main difficulties of migration. Road building and improved infrastructure for travel are important parts of increasing productivity for migratory beekeepers, but reliable transportation is a complex problem in Himachal Pradesh as mountain roads are difficult to maintain and increase landslide risk.

Beekeeping Method and Altitude Impact a Beekeeper's Perception of Climate Change

Several factors can influence a beekeeper's perception of the changes in their environment, including altitude and method. Climate change occurs slowly and is sometimes difficult for humans to detect as a result (Scott et al., 2016). Higher altitude ecosystems are more sensitive to climate change, so beekeepers at higher altitudes are more likely to notice climate change.

Box hives and beekeeping with *A. mellifera* require more surveillance of the hives and more maintenance than stationary methods with *A. cerana* and indigenous hive types. Beekeepers using a method that requires more maintenance are more likely to notice slow changes occurring in the environment or subtle changes in colony health and bee activity. Additionally, *A. mellifera* is more sensitive to environmental changes, so colonies of *A. mellifera* are more likely to demonstrate noticeable changes than colonies of *A. cerana*. One stationary beekeeper we interviewed had about a dozen box hives of *A. mellifera*, which requires more flora to survive and produce honey (beekeeper 1, personal communication, March 16, 2024; H. K. Sharma, personal communication, April 17, 2024). This is one possible explanation for why this beekeeper was so aware of changes in floral availability and pests despite his low altitude.

Since migratory beekeepers are always moving to a location during the prime flowering time in that region, they are less likely to recognize if or how the seasons have changed with

time. However, they are likely the most aware of how flowering patterns change in each of the locations on their route.

Beekeepers that rely on their bee products for income are more likely to notice changes. Industrial beekeepers that measure and sell their honey are more likely to notice changes in their honey production than beekeepers who extract honey for their own use. Box hives allow for easy honey extraction without destroying the honeycomb, but wall hives require that beekeepers destroy some of the comb in order to extract honey. It is likely that extraction from wall hives is less accurate, so beekeepers using indigenous methods cannot measure their honey production over time as accurately.

We expect beekeepers using box hives and *A. mellifera* to notice climatic changes before beekeepers using indigenous methods or box hives with *A. cerana*. Indigenous methods make it more difficult for beekeepers to notice change because they are better adapted to the local climate and less labor intensive. Industrial methods are more sensitive to environmental changes and therefore allow beekeepers to notice changes more easily.

The CALENDARS Project

Our research sought to answer the following research questions to contribute data to the CALENDARS project:

1. How have beekeeping practices and technological tools that support beekeeping changed?
2. What is the future outlook for beekeeping as described now by beekeepers?
3. What climate change indicators and vulnerabilities are reported?

How have beekeeping practices and technological tools that support beekeeping changed?

Beekeeping in Himachal Pradesh is shifting away from indigenous methods in order to increase profitability. The use of *A. mellifera* is growing in popularity because it produces more honey than the indigenous honey bee, so technology and tools for beekeeping have changed to support the use of a different bee species. Box hives, pest treatments, and industrial tools for honey extraction and processing are increasing in popularity as more beekeepers take on an interest in beekeeping for profit. Box hives are more sensitive to changes in the environment and require adaptations to cope with temperature variation. These adaptations are discussed in the analysis section of this paper. *A. mellifera* is most productive when migrated throughout the year

in order to avoid cold temperatures and provide constant access to nectar sources. Migratory beekeeping as an adaptation is discussed in more detail in Chapter 4: Results and Discussion.

As tools and techniques change, education about beekeeping in Himachal Pradesh has changed as well. Beekeepers are increasingly reliant on information from scientists and technical experts in order to successfully use new methods.

What is the future outlook for beekeeping as described now by beekeepers?

Migratory beekeeping is currently the most productive method of beekeeping in Himachal Pradesh. Beekeepers in Himachal Pradesh migrate to the plains regions of India during the winter, and beekeepers in the plains migrate to the mountains during the summer (beekeeper 6, personal communication, April 17, 2024; beekeeper 8, personal communication, April 21, 2024; H. K. Sharma, personal communication, April 17, 2024). This relationship means that migratory beekeeping in India is likely to be sustainable long term. The mountainous regions of North India experience long dearth periods, with no access to nectar sources, during the winter. Plains regions experience dearth periods during the summer. As a result, colonies from the mountains and from the plains are not in the same place at the same time competing for the same flora.

The introduction of commercial, migratory beekeeping has provided the opportunity for beekeepers to use indigenous beekeeping methods as a recreation rather than for profit.Migratory beekeeping is productive and profitable, and some migratory beekeepers keep stationary hives of *A. cerana* in their homes but do not necessarily sell the *A. cerana* honey. *A. cerana* honey is more expensive than *A. mellifera* honey, so selling the additional honey produced with indigenous methods could be an effective way to supplement a beekeeper's income if desired.

As is mentioned above, indigenous methods of beekeeping are robust against climate change and require less maintenance. However, the lower honey production makes these less viable as a large-scale adaptation, and the other problems affecting beekeeping distinct from climate change still threaten indigenous methods.

Beekeepers are primarily concerned about non-climate threats to their livelihoods. The non-climate concern mentioned by most beekeepers as a worry was pesticides, which reduces honey production by killing bees and contaminates honey, lowering honey quality. One beekeeper reported that they may no longer be able to continue beekeeping if pesticide use increased. Beyond pesticides, beekeepers are also worried about changes from urbanization and increased agriculture. Deforestation for construction and roadbuilding, along with increasing use

of monoculture agriculture, have reduced flora diversity and density, making it harder for bees to find food and reducing honey quantity. A beekeeper also mentioned that an increase in hives in the area meant more bees were competing for the same floral resources, reducing honey production.

Some stationary beekeepers expressed concerns about the coexistence of the indigenous bee and European honeybees. Beekeepers reported aggression between *A. cerana* and *A. mellifera*, spread of disease between the two bee species, and decreased flora due to competition between the two bee species. Experts were unable to corroborate concerns about aggression between species. One beekeeping trainer we spoke to stated that hives of *A. cerana* and *A. mellifera* must be kept 3km away from each other, but the Dr. YSP University experimental apiary kept *A. cerana* and *A. mellifera* hives approximately 15-30m apart. Additionally, scientists reported that the use of *A. mellifera* bees has not damaged local ecosystems. Regardless, some beekeepers are concerned about the increase in *A. mellifera*, as the popularity of migratory beekeeping using them increases.

What climate change indicators and vulnerabilities are reported?

As discussed in Chapter 4, beekeepers have reported increased variability in rain and temperature as well as some shifts in the timing of certain seasons. The severity of the climate reported vulnerabilities generally increased with altitude. However, non-climate factors like urbanization and agriculture were reported as greater concerns by beekeepers.

Challenges

The language barrier between our team led to difficulties asking beekeepers about complex, conceptual topics. We updated our interview script to be more concise and direct to prevent confusion. As a result, we were unable to ask beekeepers to draw their calendars. Instead, we asked for details about their schedules and drew the calendars with the data we received. Some beekeepers had difficulty remembering their schedules and climate conditions in the past. Others became confused as we tried to ask conceptual questions in different ways to elicit a response that was relevant to our research. We experienced difficulty trying to consistently ask the same questions to beekeepers because each beekeeper had a different level of understanding of the topics we were asking about, so we often needed to ask more pointed questions to elicit a helpful response.

The language barrier between our team and our interviewees prevented us from talking about complex concepts of time. We were restricted to asking our interviewees about their yearly schedules in a simple linear fashion. We do not feel that this restriction has greatly limited our ability to understand the shifts in seasonal patterns that our interviewees described, but this did prevent us from understanding how the beekeepers themselves view the year. We were challenged when asking beekeepers to define the seasons of the year as they understood them.

Chapter 6: Recommendations

Calendar Web Tool

The data input into the calendar tool was generated by asking beekeepers about their schedules and manually tracking the data in a similar format to the calendars tool. The data was then transferred to the calendar tool. In transferring this data to the calendar tool, we faced problems with the interface and entering data. Past the interface issues, we also noticed some bugs in the tool and had issues sharing the data and examining it collectively.

The user interface is the primary obstacle to making this calendar tool more usable and available. The calendar tool is built to represent events spanning a range of times, but some of the events we heard from beekeepers, such as collecting honey or cleaning hives, were not events that spanned a period of time, and instead happened at a single point in time. These events are somewhat hard to represent with the current tools, and we suggest that a new type of event can be added marking that something occurs at a specific time. Text-boxes were added to the calendar tool and assist with this, but more complete support would be useful. This could be shown similar to the solstices, or could be shown as a pin. The second issue we had with the user interface was that it was cumbersome to modify events. Once an event was placed, the start date could not be modified and only the text and length of the event could be changed. To move the event vertically, a different tool had to be selected. If the various tools used to create and move events were replaced with a drag and drop system where the details are editable by clicking on an event, it would be much easier and faster to create a calendar.

Beyond the interface, we faced a bug where the events seemed to shift slightly on the calendar. We believe this is due to resizing the calendar, but combined with the inability to change the starting point of events, it resulted in some issues in creating the calendars we were aiming to create. We also found that it was difficult to share the calendar, save it, and retrieve it. As with the other groups working on this project (Arroyas et al., 2024; Ehmer et al., 2024) we believe this would be best addressed by saving the calendars to a database.

Improving the Status of Beekeeping in Himachal Pradesh

Local communities should investigate ways to limit bees exposure to pesticides, such as decreasing pesticide use by implementing natural farming or nontoxic pesticide alternatives.

Beekeepers reported switching from spraying their hives with chemicals to spraying with cow urine to get rid of pests. A similar alternative for agriculture could be a solution for sustaining the coexistence of apiculture and agriculture. Another suggestion made by a beekeeper was to spray pesticides at night since most pests are nocturnal and bees forage during the day. Scientists reported teaching beekeepers to spray crops with pesticides before the crop flowers, which is before the crop produces nectar. These options could reduce the exposure of bee populations to harmful pesticides and insecticides.

Understanding Beekeeping in Himachal Pradesh

Our research was focused on gaining empirical information about how beekeeping in Himachal Pradesh has changed, so we were unable to gather information about how the beekeeping community in Himachal Pradesh feels about climate change and modernization.

Attitude Towards Change

We did not have an opportunity to understand whether or not beekeepers were willing to change, excited to learn commercial methods to increase production, reluctant to adapt, etc. Future research can focus on the cultural and religious significance of beekeeping traditions among small scale beekeepers. We also recommend that future researchers learn how the local communities feel towards change in beekeeping practices and to their livelihoods to support changing beekeeping practices in order to better understand the future outlook of beekeeping in the region.

Beekeepers are more connected with the environment than the average person, so their indigenous knowledge provides a unique perspective on changes in the climate. Future research should use this knowledge to learn about how the traditions of Himachali beekeeping or greater Himachali culture help or hinder the community's ability to adapt to climate change.

Perceptions of Changing Seasonality

For regions like Himachal Pradesh where documentation of practices is limited, future researchers should consult with local experts. To effectively ask about beekeepers' schedules, we suggest that teams ask their interviewees when they do a specific task rather than asking what

they do at a given time. For example, interviewers should ask when the beekeeper supplements their hives with food, cleans their hives, extracts honey, etc. instead of asking what the beekeeper does during the spring.

Since we were unable to ask beekeepers to hand draw their schedules for us, we did not collect data about how beekeepers themselves visualize their calendar year. As a result, we are unable to compare actual changes in the seasons to the changes that beekeepers are feeling. We recommend that future researchers can make a template for beekeepers to demonstrate their schedules to help discuss complex concepts of perceiving changes in climate and seasonality. Future research should focus on analyzing the following factors of how beekeepers visualize the year: linear or circular, names of the seasons, and starting month.

Expert Opinions

We recommend that future teams coordinate with apicultural and entomological experts before arriving to do fieldwork to gain access to data about local climatic changes or trends in commercial beekeeping.

Information from local government agencies, like the Department of Agriculture of Himachal Pradesh, can provide data about trends in pesticide use and commercial beekeeping over time in Himachal Pradesh. This information can be used to supplement the observations of beekeepers.

Trends in Productivity

Generally, beekeepers were able to confidently report their challenges and inefficiencies over time but had more difficulty recalling changes in external factors over time. Similarly, a beekeeper reported that his honey production and bee population varied with weather and flora conditions but could not report whether there was an overall increase or decrease throughout the duration of time he has been beekeeping. A long term study recording the bee populations, honey production, and schedules and routes would provide conclusive data about how apiculture in Himachal Pradesh has changed with time.

Conclusion

Beekeepers interact with the environment more than the average person and have more insight into how the climate has changed. Himachal Pradesh has a wide range of climates due to its diverse geography and varying altitudes, so beekeepers in different locations with different methods are noticing different climatic changes and making different changes to their techniques. The seasonality of beekeeping in Himachal Pradesh has shifted as the climate has changed. Some beekeepers reported that the seasons of beekeeping occur at different times than they used to, but they did not report this as a primary concern. Beekeepers in Himachal Pradesh are seeking to increase their production and profit, so education on industrial beekeeping techniques should keep up with increasing trends in beekeeping for profit to ensure productivity. The most reported concern from beekeepers was increasing pesticide use in the agricultural sector. Overall, beekeepers and apicultural experts are of the opinion that migratory beekeeping is a sustainable solution to continue productive apiculture.

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Appendices

Appendix A: Guide to Beekeepers Interviewed

Guide to beekeepers that were interviewed and interview dates. Each beekeeper has been arbitrarily assigned a number for reference in this report.

Beekeeper	Interview Date	Location	Elevation (m)	Bee Species	Hive Type	Method
1	March 16	Chamah	1000	*A. Mellifera, A. Cerana*	Wall, Box	Stationary
2	March 20	Shegli	1400	*A. Cerana*	Wall	Stationary
3	March 20	Shegli	1400	Unspecified native species	Wall	Stationary
4	March 27	Gumma	1189	*A. Cerana*	Box	Stationary
5	March 29	Naggar	1800	*A. Cerana*	Log, Mud, Box	Stationary
6	April 17	Kullu	100-4270	*A. Mellifera*	Box	Migratory
7	April 21	Bajaura	2780	*A. Cerana*	Wall	Stationary
8	April 21	Bajuara	60-2780	*A. Mellifera*	Box	Migratory

Appendix B: Summary of Changes and Challenges Reported by Beekeepers

Location	Weather Shifts	Season Shifts	Flora Shifts	Beekeeping Shifts	Difficulties
Chamah	Warmer temperatures		Flowers dry up earlier		Decreased honey production (due to bees competing for resources)
	More cloudy summer days		Loss of trees/shrubs to road construction		
Shegli	Warmer temperatures	Spring prolonged 10 days (10yrs)	Some flowers bloom earlier	Bees become active 20 days later (10yrs)	-50% Honey production
		Summer starts/end 20-25 days later (10yrs)	Rhododendron blooms 1 month later and shorter		Bee population decreasing (due to pesticides/insecticides)
		Monsoon prolonged 20 days (10yrs)	Decreased flora availability (due to deforestation and agriculture)		Increase in wax moths
Shegli	Warmer temperatures in summer		Flowers blooming/dying 1 month earlier (20yrs)	Extracts honey 25-30 days earlier (20yrs)	-50% Honey production (20yrs)
	Colder temperatures in winter			Bees starting/leaving hibernation 10-15 days earlier (20yrs)	-60% Bee population (20yrs)
	Decreased annual rainfall			Bees only make 1 new colony a year (2-3 new colonies 20 yrs ago)	Pesticides kill bees and lower honey quality
					Increase in mites
Gumma	Warmer temperatures	Summer delayed 10-15 days	Flowers bloom 10-15 days later	Bee colonies divide 10-15 days later (due to cold temperatures)	Decreased honey production
	Snowfall delayed 30-35 days (10yrs)	Monsoon delayed 10-15 days		Bees more aggressive (due to high temperatures)	Bee population decreasing (due to pesticides and lack of wall hives)
	Colder temperatures around Feb-Mar				
Naggar	Warmer temperatures		Decreased flora availability		-20-25% Honey production
	More extreme weather				Pesticides kill bees and lower honey quality
	More heavy rain				Increase in disease
Bajaura	Variable temperatures	Seasons delayed by 10 days	Flowering delayed by 10 days		Drastically decreased honey production from local bees
	Variable rainfall		Decreased flora availability (due to increased monoculture)		Variable weather and flora dictate colony population and honey production
			Variable flora availability		

Location	Migratory Route	Shifts	Challenges
Bajaura	Kullu Haryana Utter Pradesh Rajasthan Haryana	Decreased flora availability	Decreased brood size
		Decrease in wild flora	Decreased nectar production
		Increase in agricultural crops	Pesticides
			Transporting the bees
Kullu	Kullu Lahaul Haryana Rajasthan Haryana	Flowering 7-10 days early	Decreased brood size and bee population because of pesticides
		Migration time is variable by +/-10 days	Dereased nectar production
		Higher temperatures	Poor road conditions
		More dry periods	

Appendix C: Frequency of Adaptations made by Beekeepers

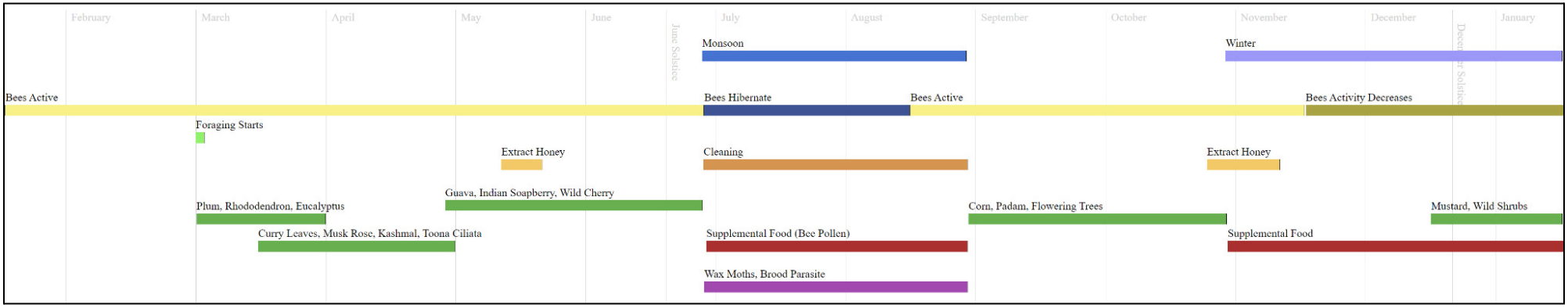
Adaptation	**Frequency (stationary)**	**Frequency (migratory)**
Switch to box hives with *A. mellifera*	2	0
Switch to indigenous methods with *A. cerana*	1	0
Insulate box hives to cope with cold	1	0
Ventilate or spray box hives to cope with heat	2	0
Begin supplementing with food	2	0
Changed techniques after receiving more education	2	0
Rent colonies for pollination	0	2
Keep *A. cerana* not for profit	0	1
Opt for natural pest repellents and natural farming	1	0

Appendix D: Beekeeping Calendars

On the next pages are beekeeping calendars generated by the calendars tool.

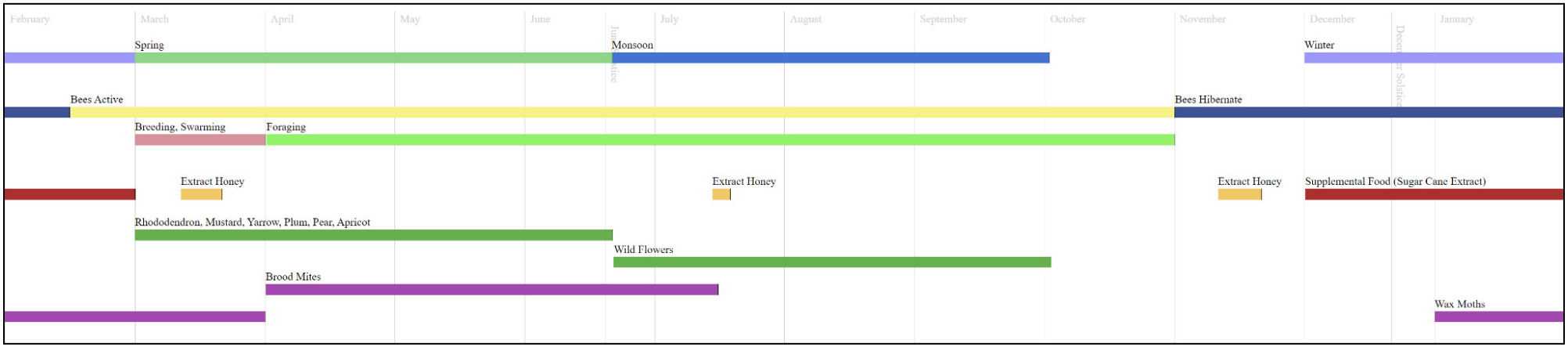
Beekeeper 1: Chamah, 1000m, stationary

Current Calendar



Beekeeper 2: Shegli, 1400m, stationary

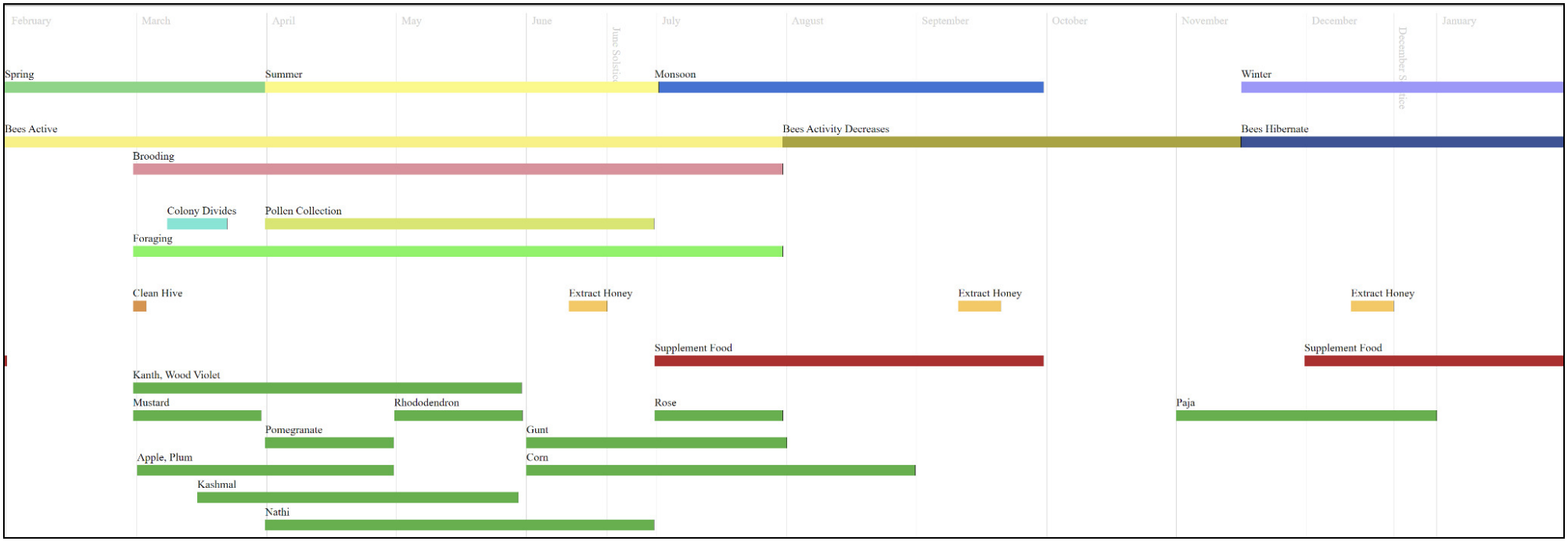
Current Calendar



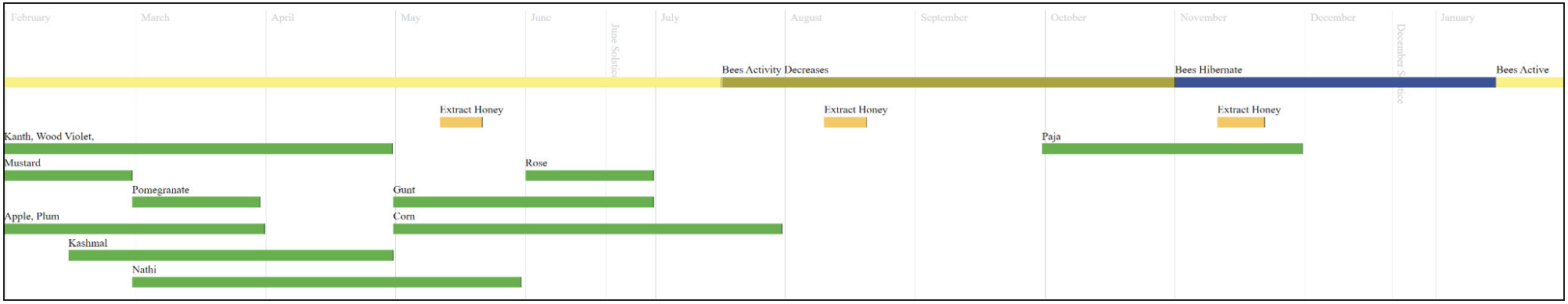
Past Calendar (10 years ago), only shifted events shown

Beekeeper 3: Shegli, 1400m, stationary

Current Calendar

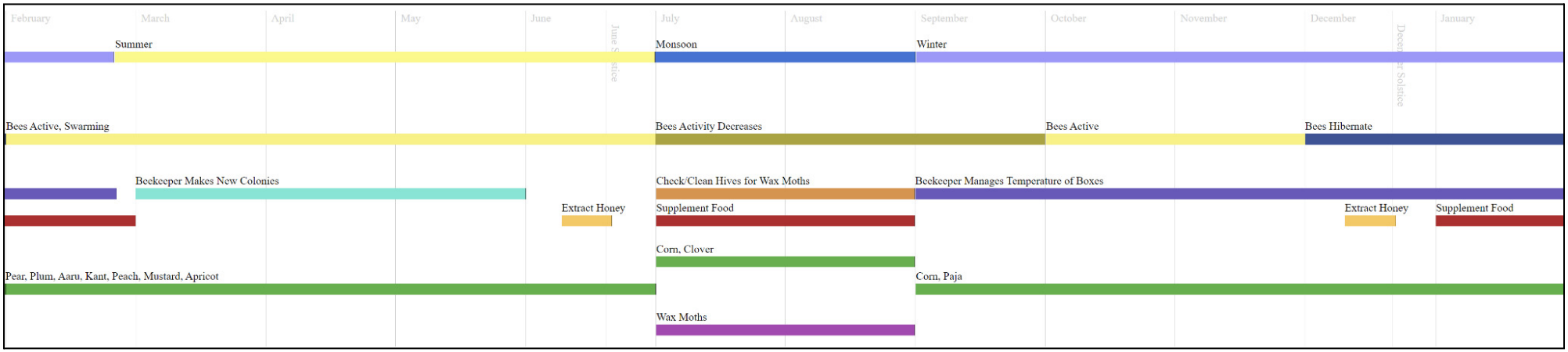


Past Calendar (20 years ago), only shifted events shown



Beekeeper 4: Gumma, 1189m, stationary

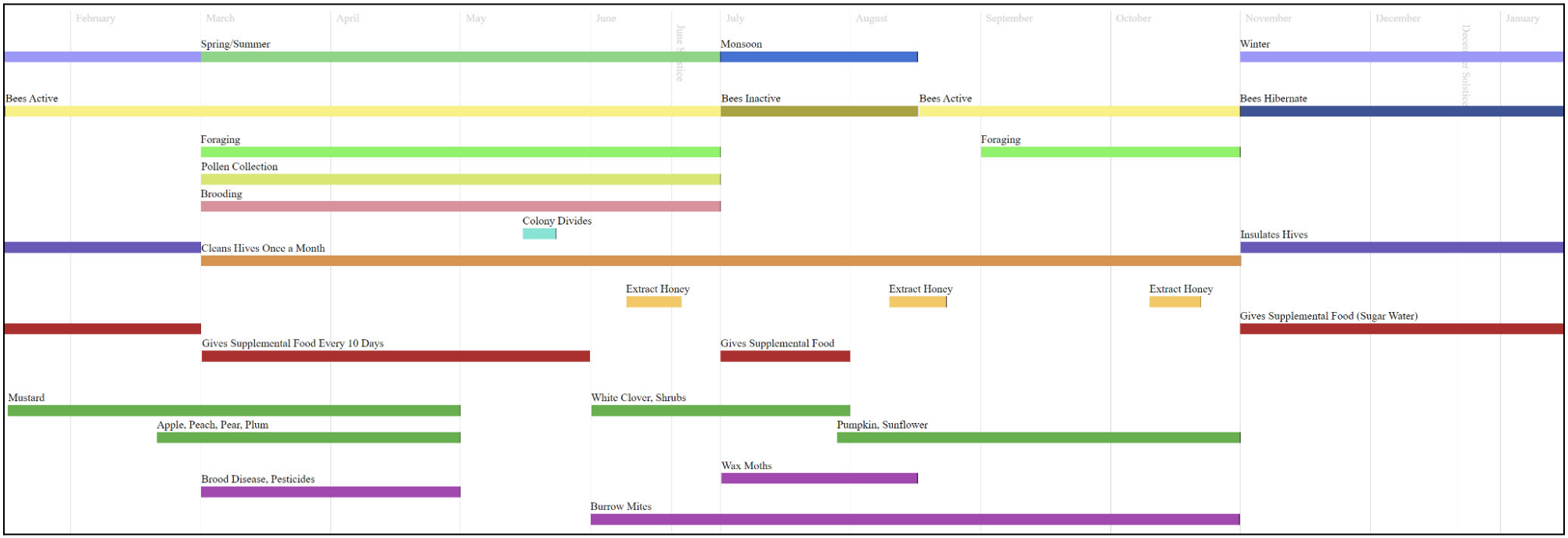
Current Calendar



Past Calendar (10 years ago), only shifted events shown

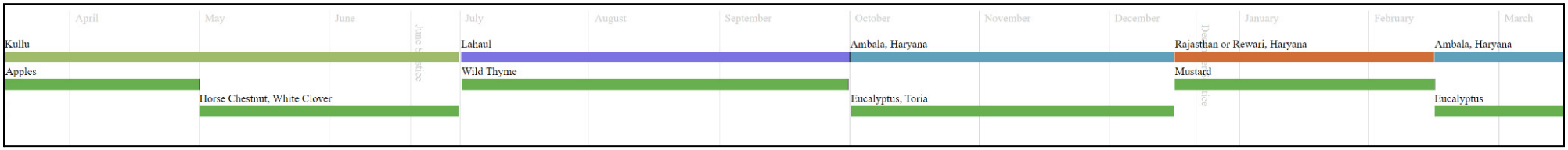
Beekeeper 5: Naggar, 1800m, stationary

Current Calendar



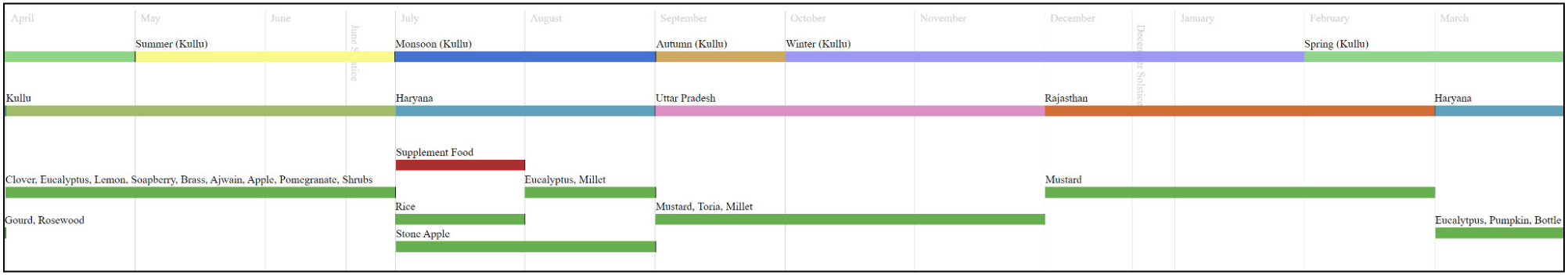
Beekeeper 6: Kullu district, 1278m, migratory

Current Calendar



Beekeeper 8: Bajaura, 1375m, migratory

Current Calendar



Appendix E: Stationary Beekeeper Interview Questions

Preamble

We're interested in learning how climate is affecting beekeepers. We've read that beekeepers in other parts of the world are experiencing changes, such as reduced hibernation periods, an increase in pests, and a decrease in nectar/pollen sources. We're interested in how beekeepers in this area are impacted by climate and the development of the region, so we'd like to ask you some questions about your beekeeping.

Background Questions

- How long have you been beekeeping? Have you been working in the same village the whole time?
- How did you learn beekeeping?
- Are you a professional/full-time beekeeper?
- Are there other beekeepers in this area?
- Do you work with other beekeepers? Do you teach other beekeepers?

Beekeeping Practices Questions

- What species of bee do you keep?
- What tools do you use?
    - Do you use different tools now than when you started beekeeping? **Why?**
- What hives do you use?
    - Do you use the same hive type now as when you started beekeeping? **Why?**
- Do you practice migratory or stationary beekeeping? Something else?
    - If migratory, when and where do you move your hives throughout the year?

Calendar Questions

- What are the seasons of beekeeping?
- For each season they mention:
    - When is the season?
    - When was the season 10 years ago?
    - What are the main nectar/pollen sources in that season?
    - What do the bees do during that season?
    - What do you do for the bees during this season?
- Do you supplement your colonies with food?
    - If yes, when and why?
    - If yes, have you always supplemented your colonies with food?
    - Do you supplement more food now than 10 years ago?
- IF NOT ANSWERED: When do you clean your hives?
- Are there any pests or diseases affecting your bees?
    - When do they appear?
    - Were they a problem 10 years ago?

    - When did they appear 10 years ago?
    - Have they increased in the past 10 years
    - How do you manage these pests/diseases?
    - Have your methods changed?
- How much honey do you collect with each harvest?
    - How much honey did you collect with each harvest 10 years ago? More? Less?
    - What do you do with your bee products? Sell? Use for self?

<u>Climate Change Questions</u>

- For the nectar/pollen sources previously mentioned:
    - Do you observe plants flowering at different times of year than they used to?
    - Do you observe flowers drying out/up at different times of year than they used to?
    - Are these plants as available as they used to be?
    - Are there plants present now that weren't available when you began beekeeping in this area?
    - Are there plants that are no longer present in this area?
- For important pollen sources:
    - When does the plant first bloom, when did it first bloom 10 years ago?
    - How long does the plant flower for, how long did it flower for 10 years ago??
- Has there been an increase in chemical pesticides or fertilizers?
    - When did they start being used?
    - How do they affect the bees?

<u>Seasonality/Adaptation Questions</u>

- How are you coping with changes in climate?
    - What adaptations have you made? **Why?**
    - Are the bees adapting?

<u>Livelihood questions</u> (*focus on if the beekeeper sells products for profit)

- What else do you participate in during the year?
    - Are these activities influenced by changes to your beekeeping schedule?
    - How does your beekeeping schedule interact with other parts of your life?
- What is your primary source of income?
    - How much money do you make from selling your bee products?*
    - Has the price of honey changed?
    - Has your income changed?
- What challenges have you faced in beekeeping?
    - Have you ever considered stopping? If so, why?
- What hinders your productivity?*
- Are you interested in scaling up your beekeeping?*
    - If yes, what resources would you need to be successful?*
- How do you feel about the future of your beekeeping?

Appendix F: Migratory Beekeeper Interview Questions

Preamble

We're interested in learning how climate is affecting beekeepers. We've read that beekeepers in other parts of the world are experiencing changes, such as reduced hibernation periods, an increase in pests, and a decrease in nectar/pollen sources. We're interested in how beekeepers in this area are impacted by climate and the development of the region, so we'd like to ask you some questions about your beekeeping.

Background Questions

- When did you start beekeeping? When did you start practicing migratory beekeeping?
- How did you learn beekeeping?
- Are you a professional/full-time beekeeper?
- Do you work with other beekeepers? Do you teach other beekeepers?

Beekeeping Practices Questions

- What species of bee do you keep?
- What tools do you use?
    - Do you use different tools now than when you started beekeeping? **Why?**
- What hives do you use?
    - Do you use the same hive type now as when you started beekeeping? **Why?**
- Do you practice migratory and stationary beekeeping?
- Describe your migration route.
- FOR EACH STOP:
    - If not answered, how long are you there?
    - How do you know when to move between stops?
    - What are the nectar sources for your bees?

Calendar Questions

- What are the seasons of beekeeping?
- For each season they mention:
    - When is the season?
    - When was the season 10 years ago?
    - What do the bees do during that season?
    - What do you do for the bees during this season?
- Do you supplement your colonies with food?
    - If yes, when and why?
    - If yes, have you always supplemented your colonies with food?
    - Do you supplement more food now than 10 years ago?
- IF NOT ANSWERED: When do you clean your hives?
- Are there any pests or diseases affecting your bees?
    - When do they appear?
    - Were they a problem 10 years ago?

    - When did they appear 10 years ago?
    - Have they increased in the past 10 years
    - How do you manage these pests/diseases?
    - Have your methods changed?
- How much honey do you collect with each harvest?
    - How much honey did you collect with each harvest 10 years ago? More? Less?
    - What do you do with your bee products? Sell? Use for self?

Climate Change Questions

- Has the time you move your hives changed over the past 10 years? Why?
- Have the places you move your hives to changed over the past 10 years? Why?
- For the nectar/pollen sources previously mentioned:
    - Do you observe plants flowering at different times of year than they used to?
    - Are these plants as available as they used to be?
    - Are there plants present now that weren't available when you began beekeeping?
- Has there been an increase in chemical pesticides or fertilizers?
    - When did they start being used?
    - How do they affect the bees?
    - Does your migratory route change to avoid pesticide exposure?

Seasonality/Adaptation Questions

- How are you coping with changes in climate?
    - What adaptations have you made? **Why?**
- What problems do you face while migrating?

Livelihood questions

- What else do you participate in during the year?
    - Are these activities influenced by changes to your beekeeping schedule?
    - How does your beekeeping schedule interact with other parts of your life?
- What challenges have you faced in beekeeping?
    - Have you ever considered stopping? If so, why?
- How do you feel about the future of your beekeeping?

Appendix G: Scientist Interview Questions

Flora Questions

- How has flower availability changed over time?
    - In response to pesticides, temperature changes, etc.
- When do important flora bloom and how long are they in bloom for? Has it changed? Why?
- What native and non native flora are available for bees?
    - Wildflowers vs. agricultural crops

Pest Questions

- How have pest populations changed over time? Why?

Bee Questions

- Bee schedule
    - When do bees hibernate?
    - When do bees swarm?
- How has changes in weather affected bee behavior?
- How has pesticide use affected bee behavior?
- How has the reduction of wild flora affected bee behavior?
- How has the introduction of non native crops affected bee behavior?
- How has the introduction of the Apis Mellifera affected local ecosystems?
- We talked to a beekeeper who was raising both Apis Cerana and Apis Mellifera, and said that they were mingling and interbreeding. How do Apis Cerana and Apis Mellifera cooperate?
- Are bees without human contact responding to climate change differently?
- Has the survival rate of bee broods changed over time?
- Has the average bee population in a given hive changed over time?

Migratory Beekeeping Questions

- What beekeepers need to practice migration? Where do they migrate to and from?
- When do beekeepers migrate?
- How do beekeepers know it is time to migrate?
- Have migration patterns changed in the past 10 years? Do beekeepers migrate at different times than they used to? Do beekeepers migrate to different places than they used to?
- Has there been an increase in the number of commercial beekeepers?
- What is the future outlook of migratory beekeeping? Is it sustainable?
- Are there any concerns with prolonged migratory beekeeping in India? What are they?
- What are the reasons beekeepers supplement their hives with food?
- Have beekeepers always needed to supplement their hives? Why?
    - Is food supplementation related to decreasing flora availability?