WPI

CALENDARS
Co-production of Seasonal Representations for Adaptive Institutions

Examining Shifts in Beekeepers' Seasonal Perspectives and Practices

Hong Kong Project Center - 2024

Abstract

As climate change persists as a global issue, its effects are changing the environment in Hong Kong. This project as a continuation of the CALENDARS Project, is a qualitative investigation of beekeepers' perceptions of seasonal changes in Hong Kong to better understand the effects of climate change on the beekeeping community. Through in-person interviews, our group was able to collect and analyse qualitative beekeeping and climate observations to describe beekeeping seasons within a year. This purpose was also to identify what challenges beekeepers are facing and how they adapt. Key outputs of our project include calendar visualisation tool for qualitative data and ArcGIS StoryMap educational reference.

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Beetales Ltd.
So Yuen Farm
Kadoorie Farm & Botanic Garden
Master Wong
Herbs Country
Master Chun Kwong

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The Importance of Bees & Their Seasonal Rhythms

Climatic and environmental shifts are undermining cultural frameworks and seasonal rhythms of different communities on a global scale. These changes are especially well observed by communities of people who directly engage with plants and animals that have natural lifecycle processes sensitive to climatic and environmental change. While both seasonality and apiculture are independently well-documented in the scientific literature, the intersection of these fields is an emerging academic topic with a limited number of publications. However, the seasonality of apiculture offers relevant perspectives on the global climate crisis and insight for community climate adaptation.

The critical role of bees in sustaining biodiversity and agriculture underscores the need for accessible and comprehensive information on the seasonal timings of apiculture. We have identified a lack of collected knowledge on these topics in many regions of the world, one such region being Hong Kong. Our project seeks to address the observed gap in knowledge on seasonal shifts in urban, subtropical beekeeping to better support Hong Kong beekeepers in their adaptation to climate change.

Hong Kong & Beekeeping

Hong Kong has a variety of urban environments that integrate wide ranges of natural ecosystems all of which are affected by recent changes in climate. Hong Kong is also home to numerous groups focused on environmental conservation. The local environmental conservation and preservation efforts in Hong Kong often include educational activities. Despite these efforts, there is a lack of easily accessible information surrounding the topic of climate adaptation specific to Hong Kong beekeepers. This is likely due to beekeeping being a relatively niche practice in the densely populated, urban sectors of Hong Kong.

Harry Wong (pictured in Figure 1), Cofounder of Beetales, a social enterprise dedicated to conservation in Hong Kong, stated in a South China Morning Post interview in December 2023:

"Our main goal is bee conservation because Hong Kong is not very bee friendly. Many people tend to spray insecticide to eliminate them whenever they see bees [...] What we want to do is educate the public that we don't need to be too afraid of honeybees; they are our neighbors." [1]

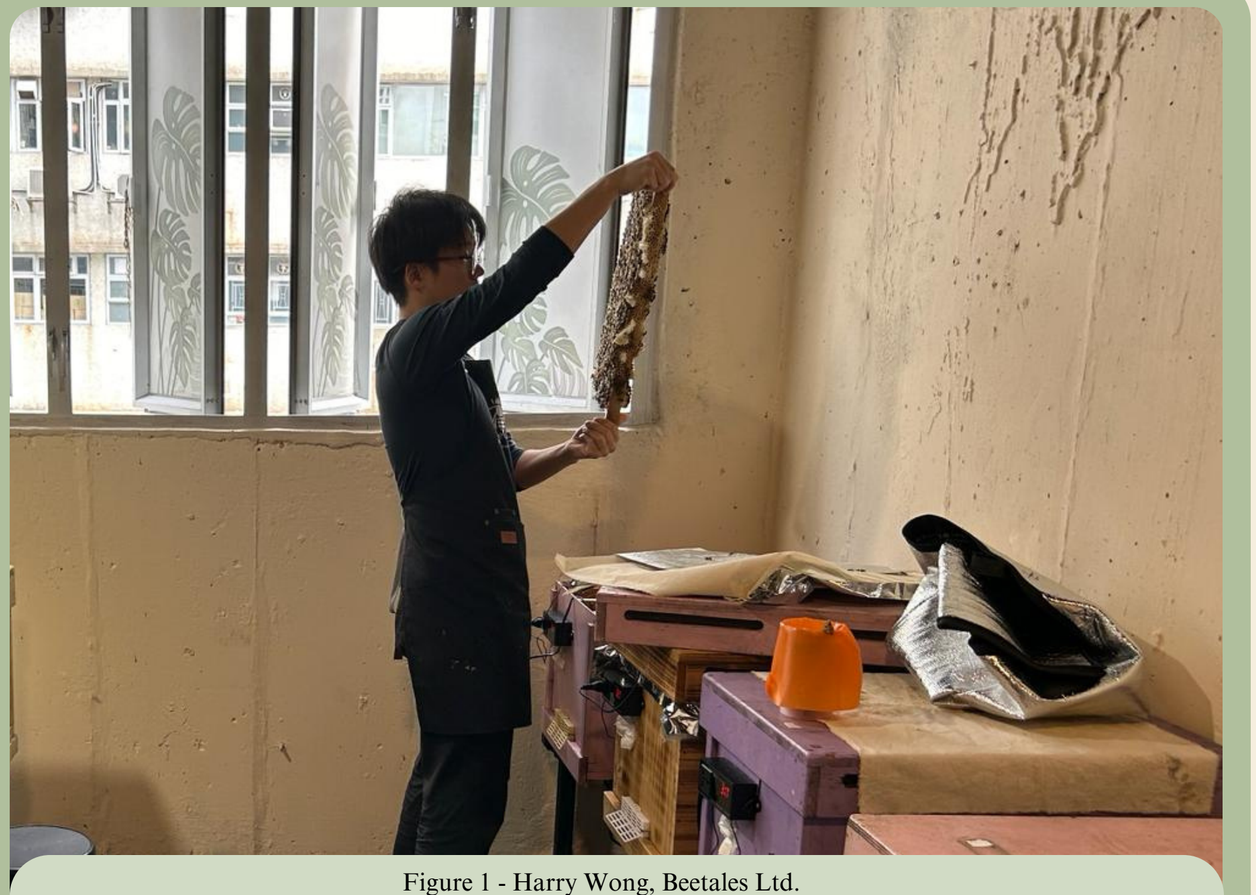


Figure 1 - Harry Wong, Beetales Ltd.

Some of the most obvious environmental changes that affect local beekeepers include fluctuations in weather and the observed migration of native plant species to higher elevations to escape rising temperatures. Generally, there is a close inter-dependency between bees and native flowering plant species; academic studies support the understanding that changes in one group drastically affect the other.[2] Effects of climate change on plants affect the food and habitat security of bees. Beekeeping is a highly experiential and regionalized activity as individuals are reliant on their personal experiences and community for knowledge. Knowledge that is best gained through experience, a lack of easily accessible academic resources, and observed changes in Hong Kong's environment, including warming temperatures, indicate that the collection and compilation of this information into a reference could provide critical insights for the beekeeping community in Hong Kong.

Apiculture as a Seasonal Activity

To understand what happens when long-held seasonal patterns of bees shift in the face of climatic and environmental change, and what this implies for climate adaptation, it is important to understand that apiculture is a seasonal activity that demands expertise in the lifecycles of bees and plants. Knowledge of seasonality can be specific to groups engaged in activities in particular places. In cases of severe change, such as with global warming or other environmental shifts, the calendars, or even cultural frameworks that people use for living and interpreting seasonal rhythms become heavily undermined.

Understanding apiculture as a seasonal activity is critical: Hoover and Hoover[3] explain that the seasonal timing of lifecycle activities in animals and plants are likely the most documented response of organisms to climate change. It is also relevant to first understand the current state of ecological systems to promote successful adaptation to seasonal change among beekeepers.

Figure 2 - Healthy Comb, Master Chun Kwong's Apiary

Figure 3 - Harry Wong (Right) and Volunteer (Left), Beetales Ltd.

Understanding the Role of Beekeepers

Beekeepers are individuals responsible for overseeing and managing the conditions of beehives (see Figure 3 & 4). One indicator for a strong and healthy hive that many beekeepers look for is a population that includes an abundance of worker bees, such as the one shown in Figure 2. This can be observed by monitoring the traffic at the entrance of the hive. Beekeepers typically inspect their hives to account for pollen stored in a hive, which is a key component to the honeybee diet. They often look for healthy brood patterns, larvae, and combs in hives. Contrary to misconceptions, abundance of honey is not proof of a current healthy colony as bees build honey stores through their active seasons and can store it for months.

Additionally, traits like the amount of honey collected are dependent on the species of bee. Many beekeepers also vigilantly observe seasonal local flowering patterns to inform their practice as bees are nutritionally dependent on available floral species. Similarly, many floral species are dependent on bees and other pollinators for their reproductive processes.

Figure 4 - Master KK, Herbs Country

Recognizing Ecological Changes & the Urgency for Adaptive Strategies

There is a growing body of literature articulating the increasingly observed phenomenon of desynchronizations in bee-plant interactions. This is sometimes described as “mismatches” between bee and plant phenology. In our context, phenology refers to the study of natural and cyclic phenomena related to plant and animal life and climate. One article from The British Ecological Society Journal of Animal Ecology is an example of the content in this growing body of articles, explaining the effects of increasingly warm temperatures on different species of bee within the research study. The author’s of the article conclude that, “…increasing spring temperatures due to climate warming may have severe consequences for bee-plant interactions”.[4] Changes in mutually dependent relationships between bees and flowering plants demonstrate a need for more research on seasonal changes, environmental change, and beekeeper climate adaptations.

Sources of Knowledge

Tacit knowledge and practice also play a critical role in decision-making in the face of climate change. Tacit knowledge is knowledge gained through lived experience, typically within a specific group that is often difficult to express. Therefore, there are inherent challenges of appraising the quality of this kind of knowledge in academia.[5] Tacit knowledge is inherently more difficult to describe than explicit knowledge, but often provides greater insight into topics that affect specific locations and groups of people. For this reason, the WPI Hong Kong CALENDARS Project incorporates observations from beekeepers in Hong Kong to inform our process and deliverables. There are many different individuals and groups that participate in keeping bees (e.g., an intergenerational family farm, a botanical garden) and they each hold different motivations. The knowledge of individual beekeepers or beekeeping groups falls on a wide spectrum, which is important for establishing what specific information they hold.

It is also relevant to consider that while beekeepers observe changes to their bees and hives, many might not have access to or be familiar with information on drivers of environmental change discussed in academic sources. Limited access to this kind of knowledge is likely related to socioeconomic status, location, and culture of the beekeepers among many other factors. Landaverde et al. articulated the lack of information about climate change and necessary adaptation strategies among novice beekeepers, that has led to difficulties planning seasonal work in locations like El Salvador.[6]

Biology of Bees

Worldwide, there are over 20,700 different species of bees. The native bee to Hong Kong is the Asian honeybee *Apis cerana*. *Apis cerana* are typically smaller than the Western honeybee, *Apis mellifera*, in body, hive, and nesting cavity size.[7] These bees are most active in March and April as nectar is most abundant then. Off-season occurs July to September when the queen bee slows down reproduction. The honeybee has four main stages in its life cycle; egg, larva, pupa and adult, shown in Figure 5.

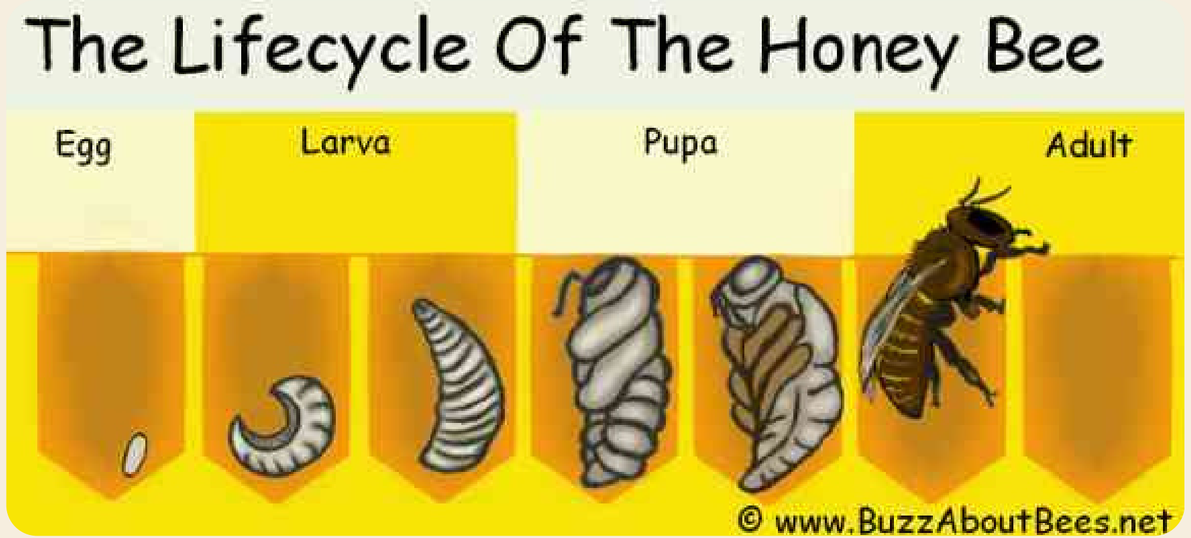


Figure 5 – Diagram: The Lifecycle of the Honey Bee [8]

Inside the Hive

A beehive is started when the queen lays its eggs in the honeycomb cells. A queen bee (Figure 6) is the largest bee in the hive, laying around 2000-3000 eggs a day. Each egg will play a vital role in the hive. As they hatch into larvae, they are nurtured by younger worker bees. The ones who are fed royal jelly, a substance produced from the worker bees' glands, after the initial larva stage will emerge as a queen bee. The queen bees' cell is noticeably larger than the others.

Female worker bees are the backbone of the hive and are responsible for the sterilization of the larvae, and the foraging of pollen and nectar. How does a worker tell her sisters when she finds a valuable source of food or water or a potential new location for a nest? They dance! Commonly known as the waggle dance, the bee will do its dance alerting the others to the distance and direction of the resource. The males develop from unfertilized eggs and are known as drone bees. Drone bees are responsible for mating with the queen and make up around twenty percent of the hives' population.

Sometimes, when a beehive becomes overcrowded an event called swarming takes place where the queen departs the nest with workers to establish a new colony, starting the cycle over. The complex social structures of beehives are often described using the analogy of a superorganism, meaning the population of bees within a hive act cohesively and as a singular unit.[9]

Figure 6 - A Queen Bee, Kadoorie Farm & Botanical Garden

Figure 7 - Bee Box, Beetales Ltd.

Apiaries & Bee Boxes

A typical beekeeping hive is man-made and includes frames for bees to build honeycombs and honey stores. Each hive design caters to various preferences and objectives in beekeeping. For example, many beekeeping hives allow the beekeeper to remove frames for inspection and maintenance. Apiaries offer numerous advantages, including minimizing the risk of significant losses, providing accessible resources for hive care, and facilitating valuable data collection on colony traits. Apiaries may take special precautions to protect hives from external factors such as predators, parasites, bacteria, and viruses.

Figure 7 displays a bee box, containing wooden frames with wire or string hung horizontally across each frame so that the bees can structure their honeycombs. A piece of fabric or foil is then placed over the hive to keep it insulated, then the lid to the box is secured on top.

An apiary, derived from the Latin noun "apis" meaning bee and the Latin suffix "-arium" meaning place, serves as the designated location for beekeeping. Also known as "bee yards," apiaries act as homes for multiple beehives and can be categorized as permanent, temporary (utilized for specific crop pollination), or mobile (transported on trucks and trailers to various locations).

Bees in Agriculture & Biodiversity

Beekeeping of native bee species is imperative for ensuring sustainable forestry and the conservation of biodiversity, as highlighted by Kohsaka et al.[10] The intricate relationship between plants and pollinators, including birds, insects, and notably bees, is fundamental for agriculture and biodiversity. When pollinators land on flowers to collect nectar, the vital process of pollination occurs as pollen adheres to them and is subsequently transferred to other flowers. Bees are crucial to terrestrial ecosystems, ensuring the continuity of this ecological process and the production of high-quality plants bearing fruits, vegetables, nuts, etc.[11] These plant communities, in turn, positively influence wildlife species relying on vegetation for both food and habitat.

Despite a reported 45% increase in population of managed beehives globally, Aizen and Harder (2009)[12] underscore a concerning trend—the fraction of global crops reliant on animal pollination has tripled, with demand outpacing supply. It is important to note that pollination is performed not only by bees but also by butterflies, beetles, moths, flies, wasps, hornets, and birds.[13] Imagining a world with insufficient pollination reveals a potential barrenness, wherein human diets would shift towards a reliance on corn, potatoes, and other crops that do not require pollination. Such a dietary shift poses a risk of malnourishment over time due to the lack of essential nutrients and variety. This emphasizes the importance of preserving pollinator populations for the sustainability of ecosystems, agriculture, and ultimately, human well-being.

The Hong Kong Beekeeping Community

Beekeepers who maintain hives as a hobby, honey production facilities that operate for profit, and groups focused on native conservation exhibit different motivations.[14] Depending upon these motivations, apiculturists can differ in desired species of bee kept, number of hives, and required time commitment of upkeep. Larger production operations in some locations may find that keeping specific non-native bee species that exhibit preferred traits is more advantageous and results in higher profits than keeping native bee species. Hong Kong is an example of a location with environments that may not be suitable for non-native bee species, providing a possible explanation why there are few or no large-scale commercial bee farms. As underlined by the Hong Kong Agriculture, Fisheries, and Conservation Department, conservation organizations like botanical gardens tend to prioritize keeping native flora and fauna and preserving natural ecosystems in their local area.[15] Herein lies a crucial difference in motivations and practices throughout beekeeping communities.

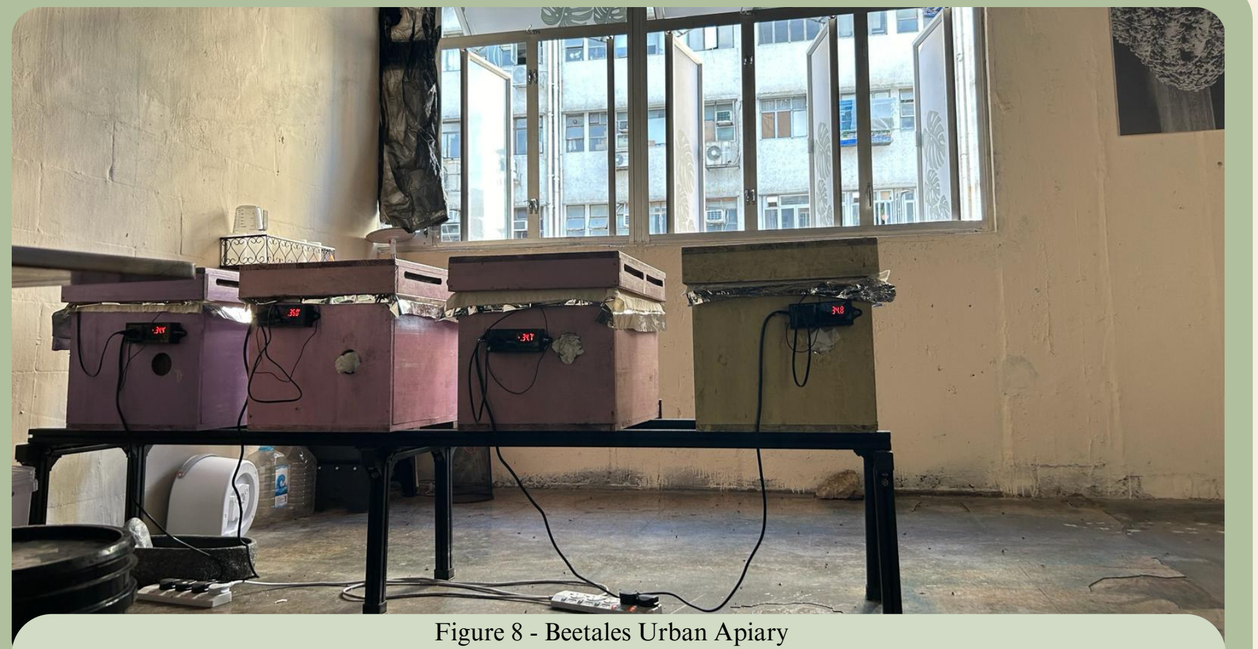


Figure 8 - Beetales Urban Apiary

Urban Apiaries

Although apiaries are traditionally kept in rural fields, many urban apiaries have begun to appear around the world in a variety of climates, such as the one pictured in Figure 8. The recent decline of bees has threatened pollination in agriculture and ecosystems globally, thus there has been a growing interest in beekeeping in metropolises and cities.[16] The urban environment possesses its own advantages and disadvantages for beekeepers. The closer proximity of humans, for example, puts bees at much greater risk to the consequences of industrialization, such as heavy pollutants or higher temperatures due to disproportionate heat in urban areas, referred to commonly as the Urban Heat Island Effect. Wild bee populations are also often perceived as pests and have their hives exterminated if present near highly populated areas.

Although urban apiculture presents a difficult challenge to those who pursue it, the payoff for promoting bee culture creates a strong counterbalance. Aside from the natural effects bees have on agricultural function, such as pollination and honey production as previously discussed, they also have a large positive effect on the urban community. Beekeeping in these areas has been shown to help incentivize environmental safety, education, and ecosystem sustainability.[17] Through interactive farms and botanical gardens, visitors can actively learn the importance of bees and their function in the ecosystem while these institutions also promote healthy mutualism between humans and animals.

Project Goals

The primary goal of our project is to produce a comprehensive representation of Hong Kong beekeeping that documents apiculturists' experiences and perceptions of the impact of local seasons on beekeeping practices. Our group produced a Geographic Information System (GIS) StoryMap as this representation. The secondary goal of our project is to expand upon a web application previously created by the 2022 New Zealand CALENDARS IQP[19] to record qualitative data of the apiculturists' perception of seasons, seasonal indicators, and experiences. To collect this data, our group has procured local beekeeping contacts and conducted interviews. In addition to our collected qualitative data, reliable academic articles, news sources, and current published environmental datasets have been used to better supplement our GIS StoryMap. The StoryMap provides a visual information guide of current local practices and document impressions of how beekeepers anticipate the future of apiculture in Hong Kong. Apiculturist experiences allows us to determine if perceptions of seasonality are changing and how these changes affect the relationship between people and their natural environment, i.e. beekeepers and their bees.

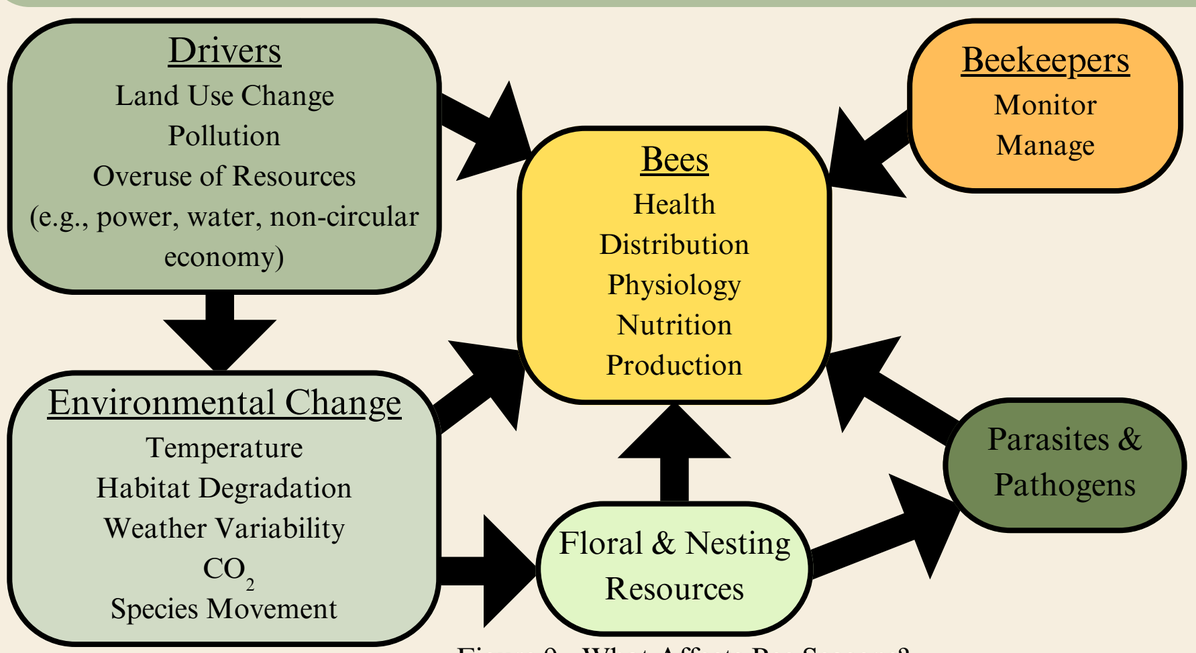


Figure 9 - What Affects Bee Seasons?

Characterizing Apiculturist Perspectives

The first objective is to gain information from local Hong Kong beekeepers via personal interviews. Our initial research on beekeeping and seasonality, as well as our preliminary interview with a master beekeeper in the United States has shown that beekeeping is highly experiential; beekeeping practices vary depending on the region, education, and organizational goals (see Figure 9).

Through our preliminary research on bees, beekeeping, and the environment of Hong Kong we have observed that academic literature on urban subtropical apiculture is limited in general, as well as specific to the Hong Kong location. To address this, we have broadened our sources to include online media such as news articles and videos to gain a better understanding. We have identified that primary sources, such as directly interviewing beekeepers in Hong Kong, are necessary for creating a comprehensive representation of a seasonal year of Hong Kong beekeeping. Interviews will consist of semi-structured, conversation-based discussions and visits to beekeeping sites.

Language & Bias

One challenge we anticipated is effectively networking with beekeepers in Hong Kong given the language and time constraints. Initial research has shown that there is a small number of beekeepers in Hong Kong, most of which are not able to converse in English. Beekeeping groups are small and independently run with no central body facilitating the practice, unlike in countries like the United States where associations such as the American Beekeeping Federation exists. The main constraint with contacting and interviewing beekeepers in Hong Kong is the language barrier; our group primarily speaks English. To overcome this, our team has employed the aid of multiple translation applications, such as the DeepL AI model, as well as help from local peers and a Cantonese speaking professor. The individuals and groups contacted for interviews include botanical gardens, farms, individual hobbyists, researchers, storefronts that sell local honey products, and online chat groups affiliated with beekeeping.

Another challenge we anticipated is preventing qualitative interview bias given our project's close relation to climate change. We phrased interview questions carefully so as not to influence interviewees' opinions or the information they shared. Following advice from anthropologists to[18] maintain an empathetic, observational perspective have developed interview questions that encourage interviewees to discuss the nuances of their experiences without directly implying causation.

Figure 10 - CALENDARS Visualisation Tool Example

Expanding Data Visualisation Tool

The second objective is to further develop the static front-end webpage of the previous 2022 New Zealand CALENDARS IQP[19] for the purpose of qualitative data collection per request of the project sponsor. To accomplish this, our team developed a functional, standalone web application (see example Figure 10). This entails modularising the application so that it can be run in separate environments. This also involves communicating with the sponsor of our project to integrate this web application into their own infrastructure. The purpose of this web application is to record seasonal observations of beekeepers interviewed in our project and allow for standard ways to compare information gathered. This tool will be used as an additional means of collecting data specific to the beekeeping community such as seasonal cues, timing of cues, number of seasons, and length of seasons. These metrics will ultimately inform an intuitive GIS Map representation of a seasonal year of beekeeping in Hong Kong.

Our biggest challenge with this objective was the timeline. Entries could not be made in the tool until it was in a functional state. In addition to this, the given front end of the web application is not user-friendly and does not include Cantonese as a language option. This aspect will not be addressed by our team as it is outside the scope of our project. We are primarily concerned with creating a representation of a seasonal year of beekeeping and providing contributions to the web application to ensure it functions.

Representing a Year of Beekeeping in Hong Kong

Our third objective is to structure our GIS Map and StoryMap in ArcGIS to represent a seasonal year of beekeeping in Hong Kong. GISs are useful tools for storing climate data and general environmental information. GIS tools allow users to create layered maps from a variety of data sets and aid in the creation of helpful visualizations of environmental variables. Layering several attributes on top of each other can provide a deeper understanding of the relationships between environmental variables in an area, especially in areas that are underrepresented in scientific literature. StoryMap features allow for the inclusion of tacit or qualitative information on top of available environmental data sets. StoryMaps are also more user-friendly than the base GIS software. Our intention is to interview local beekeepers and use ArcGIS to create a comprehensive StoryMap page using auditory and visual components gathered through a media field kit from Worcester Polytechnic Institute. Ultimately, this StoryMap will serve as a reference for the Hong Kong beekeeping community and our sponsor to interact with. In addition to serving as a reference, the GIS Map will represent the complex causes and effects that surround the practice of beekeeping in Hong Kong and how local beekeepers anticipate their practices may continue to shift in the future.

The biggest challenge of creating this representation is shared with the first objective; the representation is reliant on interviews. Additionally, the scope of our StoryMap is dependent upon the availability of environmental and geographical datasets specific to Hong Kong. Visual and auditory media such as photos, video, or interview audio clips in our StoryMap representation will be included using the field media kit. The nature and scope of included visual media is dependent on the preferences of interviewees. Our StoryMap will not include any personally identifiable information, nor any other information that participants do not consent to being publicly accessible. Most importantly, our study complies with the Worcester Polytechnic Institute Institutional Review Board (IRB) regulations.

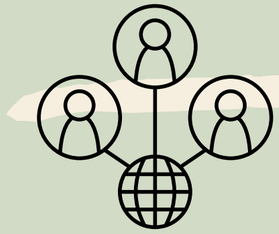
Qualitative Data Collection

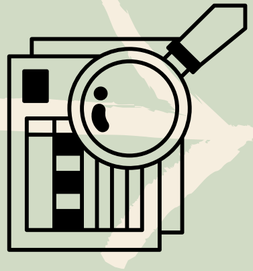
The first objective of our project was to characterize apiculturist perspectives. In our case, our group first had to procure beekeeping interviews. Our initial approach was contacting local beekeepers and small beekeeping groups with locations listed online via translated emails. Our group translated communications from English to Cantonese through the use of tools such as the DeepL AI model as well as with assistance from Professor Kelly Shum from the Chinese University of Hong Kong.

With little response, our group adjusted our interview procurement approach, expanding our interview search to local pop-up shops, gardens, online beekeeping forums, and social media searches. We also adjusted our method of contact to include calls and direct messages on various social media platforms including WhatsApp, Instagram, and Facebook. This proved more successful, allowing us set up interviews with Beetales Ltd., So Yuen Farm, and the Kadoorie Farm and Botanic Garden apiary. Meeting these groups allowed us to meet additional beekeepers. Through the duration of our project, we were able to conduct interviews at six locations in total in the New Territories of Hong Kong, shown in Figure 11.

The interview questions asked were written specifically to be open-ended, allowing beekeepers to describe their experiences without introducing leading question or wording bias. Our interview questions involved asking the participant to describe a seasonal year of beekeeping, describe their experience as a beekeeper, if their practice has changed over time, and to explain where they source their knowledge for beekeeping. Interviews were conducted in Cantonese with the help of translators. Conducting interviews using the same interview questions with different beekeepers in different locations provided comparable qualitative data. This data mainly includes personal experiences of the practice of beekeeping, as well as current and recollected past observations of how the environment and weather affect the bees.

In following sections, we compare different beekeeper's responses to our interviews, to provide insight into beekeeping seasons in Hong Kong. Interview responses also allowed us to identify the typical activities, practices, and technologies that are important for successful beekeeping in Hong Kong. These observations and analysis are supported by quantitative environmental data to provide greater context of the current environment for beekeeping in Hong Kong, and if this has changed historically.





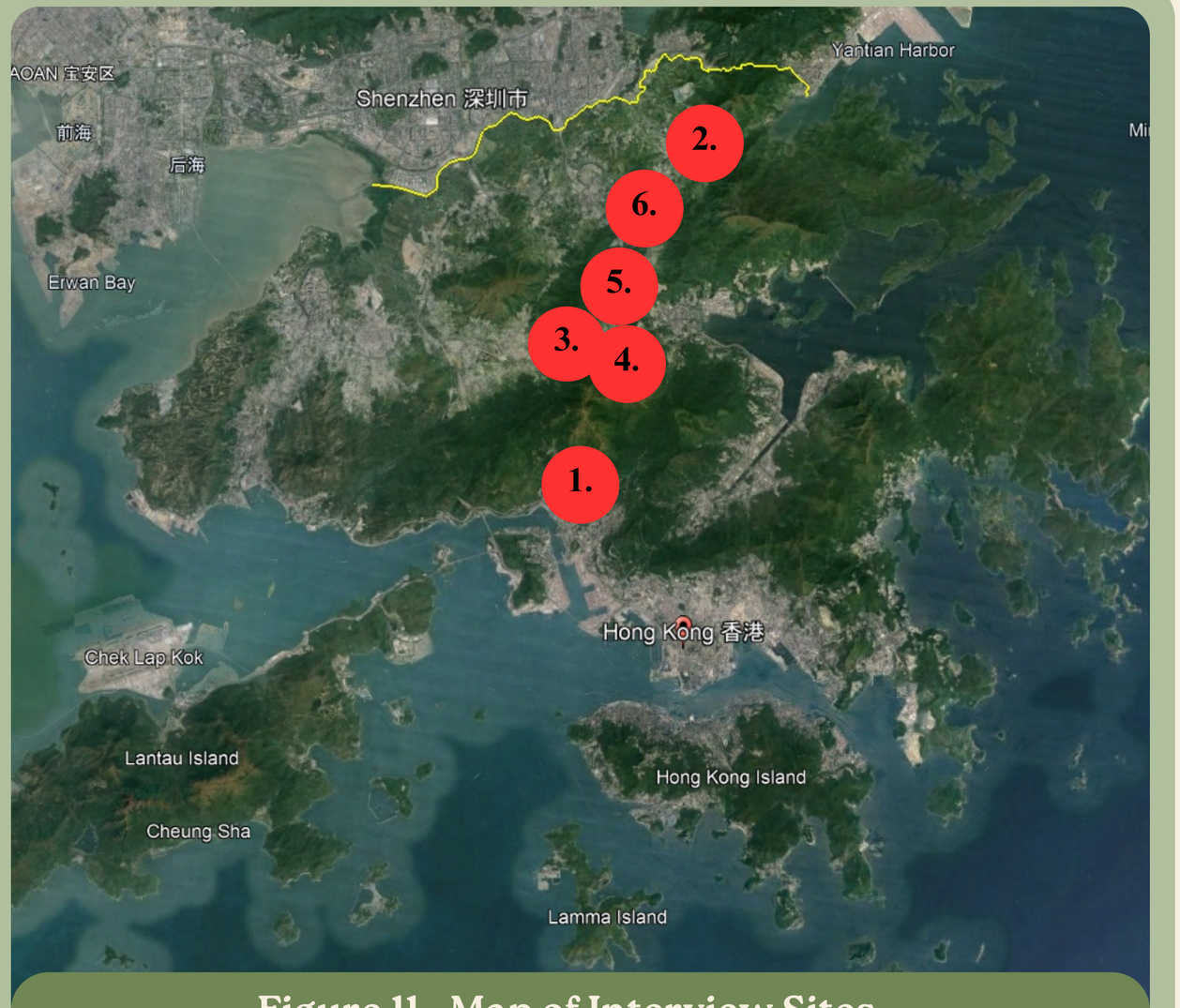


Figure 11 - Map of Interview Sites

1. Beetales Ltd.
2. So Yuen Farm
3. Kadoorie Farm & Botanic Garden
4. Master Wong
5. Herbs Country
6. Master Chun Kwong

Interview Sites

Beetales Ltd.

Beetales is a Hong Kong beekeeping organization dedicated to conservation, education, and vocation. Beetales is lead by co-founder Harry Kahon Wong. Beetales does conservation beekeeping, where they care for hives in-house and discover new ways to improve care of bee colonies.

Master Wong

Master Wong's home apiary is located close to the Kadoorie Farm and Botanical Garden apiary in the northern slopes of Tai Mo Shan. Master Wong keeps bees as a hobby. He has approximately 69 years of beekeeping experience, having originally learned the skill from his father. Master Wong is Master Lee's beekeeping mentor. Master Wong is known for his skill of catching wild bees and having a natural water source at his apiary.

So Yuen Farm

Located in Fanling, a northern, rural town in Hong Kong, So Yuen is a Bee Farm that keeps approximately 70 Apis cerana hives. While So Yuen does sell a small amount of honey at local pop-up style markets, the owners keep hives for mental health benefits rather than for economic reasons.

Herbs Country

Herbs Country is a farm established in 2017 located in the valley of the Tai To Yan Mountain range. They specialize in hydroponics, smart beekeeping, and honey production. Multiple masters and volunteers with varied experience maintain their hives. They offer educational tours to schools and groups interested.

Kadoorie Farm & Botanic Garden

Kadoorie Farm and Botanic Garden (KFBG) is a well-established conservation organization with over 148 hectares of land located on the northern slopes of Tai Mo Shan, near Tai Po, Hong Kong. KFBG is invested in ecological and sustainability issues. KFBG's on-site enclosures include an apiary overseen by two master beekeepers, Master Lee and Master Raymond.

Master Chun Kwong

Master Chun Kwong is a hobbyist beekeeper, and is the mentor of Harry Wong. His apiary is comprised of 40 hives, residing in the mountainous northern area of the New Territories which is known for various fruit trees. The natural resources allowed Master Chun Kwong to harvest in the past honey up to five times per production season, which has since reduced due to changes in the blooming seasons of the local fruit trees.

Meteorological Seasons

The Hong Kong Observatory describes Hong Kong as having different climate characteristics throughout the year which they observe through the “meteorological seasons” approach. The Hong Kong Observatory designates the warmest and coldest periods of the year as summer and winter in the Northern Hemisphere, with summer consisting of the months June, July, and August, and with Winter including December, January, and February. Between these seasons is Autumn which follows summer and includes September, October, and November. Spring, which follows winter, includes March, April, and May. Hong Kong seasons, as described by the interviewees, roughly follow these four seasons portrayed through the meteorological seasons approach. These seasons are set within the globally adopted Gregorian Calendar which separates time by twelve months, each with 28-31 days.

The Hong Kong Observatory further describes Hong Kong’s sub-tropical climate with specific characteristics, “For example, January and February are colder, July and August are hotter, June to August are rainier, while November and December are drier and less cloudy.”[21] The Hong Kong Observatory's rational for observing the meteorological seasons approach is that the length and start time of the seasons remain generally unchanged, which is beneficial for research analysis, results comparison, and communicating data both with experts and the wider public.

Apiculturist Seasons

Our first project objective is to portray perceptions and experiences of seasons in apiculture. Figure 13 was created by analysing qualitative data from interviews by extracting descriptions they share. It is important to consider that the description of beekeeping seasons developed by our group is a combined representation from separate beekeeper’s current seasonal observations. This representation also includes simplified elements from the 24 solar terms, a part of the traditional Chinese calendar as they were mentioned in about half of our interviews. This representation should only be used as a general reference as it only includes results several interviews had in common.

Recollection of both current and historical timelines or events also varied between beekeepers. It is evident that their perceptions of beekeeping seasons, or practices completed throughout a seasonal year, is dependent on the behaviour and activity of their beehives, which is highly dependent on their immediate environment. The tasks a beekeeper in Hong Kong completes from one season to another are a reaction to their hives’ condition. Beekeepers interviewed by our project group rarely create a formal forecast or plan for their year in advance (see Figure 12). Instead, they regularly inspect their hives by removing frames, visually monitoring the bees’ behaviour and food supply, and intervening when necessary. For example, frames that show a small number of bees or many punctured larvae cells are a tell-tale sign that a hive may need outside support from their beekeepers, which may not follow a strict seasonal pattern. Using regular observations and assessment of hive conditions instead of established dates suggests that physical calendars have minimal explicit influence over beekeepers’ perception of seasons.

Figure 12 - Notes Left on Various Bee Boxes Pertaining to Seasonal Remarks and Reminders

Bees, Environment, & Perception of Seasons

All beekeepers interviewed by our group mentioned that they keep the native species of bee, Apis *cerana*. The primary reason for keeping the native species is that it is best suited to the environment in Hong Kong. For example, beekeepers suggested that the *Apis cerana* is more resilient against mites than its western counterparts, *Apis mellifera*, which explains why mites are not a common threat to bees in Hong Kong. Similarly, some beekeepers suggested that while the *Apis mellifera* is better suited to commercial bee farms due to honey hoarding tendencies, the Western bee is generally ill-suited for the climate of Hong Kong.

Some beekeepers shared that when the surrounding environment provides poor resources for the bees, they must actively provide better conditions. Examples of this are providing food supplements additional food or restructuring boxes for better temperature regulation. Many observed that if they fail to provide suitable conditions for their beehives, the *Apis cerana* will relocate in search of better conditions or struggle to survive. In this way, it is essential for beekeepers in Hong Kong to adjust their practices to adapt to the changing environment through different seasons of beekeeping. Beekeepers at the Kadoorie Farm and Botanic Garden stated that wild bee populations in their location near Tai Po have also been struggling with changes in the environment.

Combined Perceptions of Beekeeping Seasons

Winter Ivy Tree Honey Production

This is one of the primary production seasons. This season is characterised by cooler temperature. The temperature of the hive should be maintained warm enough for the bees to maintain and raise their young. Many beekeepers provide insulation or other aid their beehives in regulating temperature through this season. As this is a honey production season, several of the beekeepers interviewed will not supplement their hive's food source until after harvesting honey. This ensures that the honey is primarily made from ivy tree pollen and nectar. Interviewees described this ivy tree or winter honey to be very desirable. The winter honey is known for its unique taste.

Bees Show Signs of Illness

Transition Season is the transitional period between the Fall Season and the Winter Season. It is the time of year most likely for bees to show signs of illness. Some beekeepers adjust the number of frames proportional to the population in a beehive as a preventative measure. This is typically done if bees in the hive are not fully covering all frames. Bees fully covering frames better protect bee eggs and larvae and help to maintain temperature.

Additional Food Supply

Beekeepers will provide additional food supply to their hives. This food supplement can also stimulate the hive to lay eggs and stabilise condition of the bees leading into winter season.

Fall Season

The Fall Season is preparation for the winter and spring honey production seasons. The fall is characterised by cooler weather. Many beekeepers feed their bees in preparation for the coming winter to ensure sufficient food supply as resources in surrounding environment change and reduce.

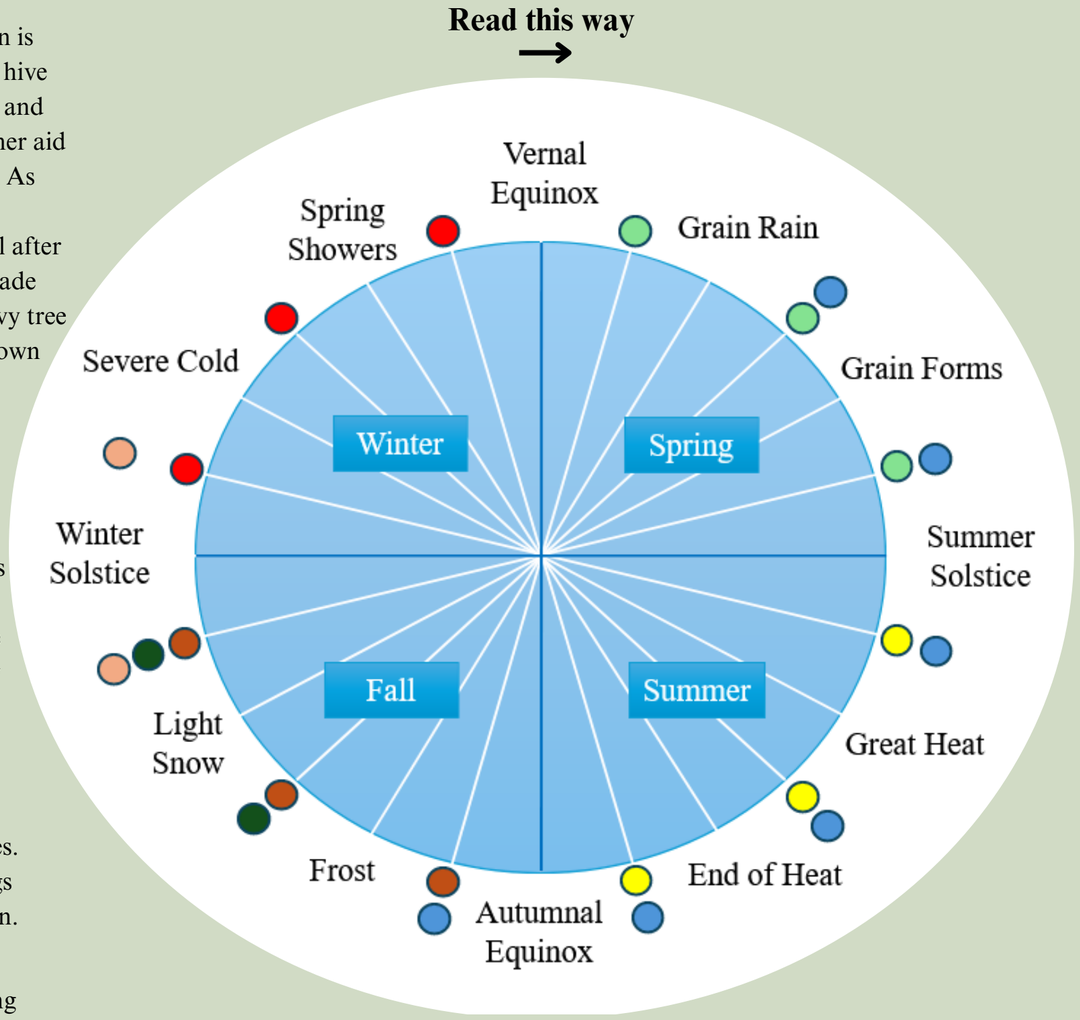


Figure 13 - Perceptions of Beekeeping Seasons from Combined Beekeeper Observations

Spring Lychee Tree Honey Production

This is the second production season, producing lychee tree honey. This season is characterised by abundant sources of pollen and nectar as plants, such as lychee trees, begin their blooming period. Years with strong production indicate better environmental conditions. Years with poor production indicate poor environmental conditions. The increase in external floral resources may cause the bees to lay more eggs.

Rainy Season

Mid-spring also marks the beginning of the rainy season that carries through summer and into early fall. Rainfall does affect bees as heavy rain will confine them to their hive. Being confined to the hive for extended periods restricts the bees' foraging, thus negatively affecting their food supply. For this reason, some beekeepers will also provide food supplements to their hive at the end of spring.

Summer Season

This season is characterized by spring flowers becoming summer fruit. This shift causes a reduction in food source for the bees. It is also the primary season in which beekeepers attempt to protect their hives from predators like wasps. Observations regarding the prevalence of wasps vary by beekeeper and site visit location. For example, beekeepers at Kadoorie Farm, located near Tai Po, specifically mentioned that they do not face a strong threat of wasps through the spring and summer seasons when natural food supply is low because the wasps also rely on floral resources for food. All beekeepers also described that they provide shade for their hives in the summer season to help their hives maintain a reasonable temperature in the hot weather.

Figure 14 - Image of a Sign Warning About the Use of Pesticides Taken at a Local Park

Challenges

Challenges identified by beekeepers in Hong Kong are dependent upon location and motivation. This observation stems from responses from different kinds of beekeepers in different locations being specific and distinctive. There is no doubt that climate change is present in Hong Kong. Several beekeepers interviewed supported the presence of climate change, and all attributed changes in the climate and weather conditions of their environment as a primary cause of many challenges they face. Beekeepers have mainly identified their challenges as widespread pesticide use, viral and bacterial outbreaks, as well as severe temperature fluctuation. Many shared observations that these challenges have become more severe in approximately the last decade. As the climate and weather conditions in Hong Kong have changed over time, local beekeepers have had to adapt their management strategies to address these larger challenges.

Use of Pesticides

The World Health Organization defines pesticides as “chemical compounds used to kill pests, including insects, rodents, fungi, and unwanted plants.”[22] Pesticides are often used in public health to kill vectors of disease like mosquitos, and in agriculture to kill pests that damage crops. It is common that pesticides are used in public parks on trees and plants, such as the treatment pictured in Figure 14. The issue in our application is that pesticides also affect unintended targets like pollinators, which are unable to detect the presence of toxic chemicals. Bees specifically will unknowingly collect contaminated pollen or nectar and spread the poisonous chemical when returning it to their hive. Many beekeepers interviewed isolate hives that show signs of contamination to prevent neighbouring hives from meeting a similar fate.

Pesticides can still affect pollinators even when they are not sprayed in their immediate environment. Beekeepers at Kadoorie Farm described an instance where somebody in the nearby area bought imported plum trees that had been grown with pesticides, resulting in the loss of multiple hives. Separately, pesticides can also affect pollinators by polluting water sources. Individuals at Beetales, explained that pesticides can run off into the water surrounding public parks, thus reducing the amount of clean water sources for bees in urban ecosystems. To adapt, Beetales provides a pool of clean water near their urban hives and plans to launch an urban oasis project to provide pollinators with clean water sources throughout Hong Kong. Other than reducing pesticide use and providing clean water sources, there is not much that can be done to prevent bees from collecting or drinking in contaminated areas.

Bacterial & Viral Infections

Beekeepers shared that it is common for hives to develop illnesses within the colder temperatures of fall and winter. Some more experienced beekeepers mentioned specifically that treating infections within their hives has become more difficult in recent years, partially due to increased presence of different kinds of viruses. We observed that disease management strategies are dependent on the type of beekeeper, personal motivations, number of hives, and willingness to use chemical treatments. The beekeepers interviewed by our project group fall on a spectrum ranging from beekeepers who describe themselves as natural beekeepers to beekeepers who describe themselves as traditional beekeepers. Traditional beekeepers are typically aligned with the stance that they will intervene with the hive if they see benefit for the health of the hive (e.g., treat the hive with soft chemicals in extreme cases of parasite infestation or illness). This is not to be confused with beekeepers who describe themselves as traditional, meaning they use traditional or historical practices. On the other hand, natural beekeepers are typically against chemical treatment regardless of the situation, and generally do not interfere with the hives, allowing nature to take its course. Our group primarily interviewed beekeepers who described their motivations as hobbyists or conservationists, and personal observations from commercial farms are not represented in this project. The beekeepers interviewed described commercial beekeepers as providing the most intervention in their opinion, followed by conservation beekeepers, then hobbyists.

Conservation beekeepers tend to provide more outside aid for overcoming the hive's sickness. Although the Eastern honeybees are quick to dispose of any bee or larva that may be sick, this process requires a lot of the colony's energy which should be spent on foraging and honey production. Harry, a beekeeper with Beetales Ltd., identifies as a conservationist and uses a tool to clean or remove sick larva cells from the honeycomb. He can tell which ones to remove because infected cells have a distinctively different colour and texture or puncture marks from bees attempting to remove the infected cell. In some circumstances, Harry will also transfer a frame of a sick hive to a stronger healthy hive with the hopes of rehabilitating the sick frame. Harry also stated that in these circumstances, commercial farms often chemically treat their hives experiencing disease. For natural beekeepers, if disease is detected, they will often isolate or exterminate the hive if conditions do not improve. Traditional beekeepers will also do this in extreme cases.

Fluctuation in Temperature

The most prevalent issues that beekeepers noted during the interviews were most commonly the result of unpredictable shifts in temperature throughout the year. Interviewees from all the locations visited stated that extreme fluctuations in temperature during individual seasons negatively affect the health and stability of their bees.

Beekeepers observe that factors such as high humidity, rain, and intense heat or cold act as stressors and result in hives behaving in unstable, irritable ways. Interviewees at So Yuen Farm and Herbs Country both stated that increasing average yearly temperatures have negatively impacted the quantity and quality of honey that they sell. Interviewees at Kadoorie Farms, Beetales, and Herbs Country also stated that extreme fluctuations in temperature affect the blooming seasons of local plants and, in turn, cause inconsistent food supply for their hives. All participants indicated that irregularities in temperature have extended the emergence period of viruses, bacteria, and certain predators such as wasps as well.

To combat the large fluctuations and worsening extremes in temperature, the local beekeepers interviewed discussed new methods they have used to better protect their hives from the weather. For example, Masters KK, Phillip, Edmond, and Zachary of Herbs Country described extreme heat as the most prominent challenge that they have faced in recent years. As a result, they have constructed a fabric canopy (Figure 14) above their hives to shade the area, as the hive location is in direct sunlight. So Yuen and Kadoorie Farm choose hive locations based on patterns of shade in their respective areas. To counter record low temperatures, the interviewees implemented several strategies. Harry from Beetales places thermometers to monitor conditions inside the hives and heating pads below each bee box to regulate and stabilize temperatures (Figure 15). Bee boxes kept at Master Wong's home apiary have a Styrofoam outer shell for insulation. Similarly, at Herbs Country, boxes are loosely covered in a plastic layer that acts to break harsh winds without restricting the movement of bees in and out of the hive.

Beekeepers also needed to intervene by feeding their hives to manage the inconsistent blooming periods of plants. All interviewees stated that they use mixtures of pollen or sugars to supplement their hives' food in periods when the surrounding environment cannot fully support the needs of the bees. Of the six beekeeping sites visited, four stated explicitly that they purchase pollen in bulk from mainland China to feed their bees, but it is likely that most if not all beekeepers in Hong Kong must do this as well.

Figure 14 - Shaded Canopy, Herbs Country

Figure 15 - Temperature Regulation, Beetales Ltd.

External Quantitative Data

The Hong Kong Observatory was our primary resource of knowledge on current and historical climatic shifts in Hong Kong. The observatory is a government department primarily responsible for monitoring and forecasting weather. One example of a relevant climatic shift occurring in Hong Kong is a significant rise in mean annual temperatures from 1885 to 2023 as depicted in Figure 17. Additionally, the observatory reports that the year 2021 was the warmest year on record with an annual mean temperature of 24.6 degrees Celsius. Specifically, the months of March, May, and September broke historic monthly average temperature records. The Observatory reports an upward trend in the annual total of Very Hot Days, where temperatures exceed 33 degrees Celsius, within the last 10 years (Figure 18). Records for the number of Hot Nights and Very Hot Days were broken as well.

In addition to rising temperatures, Hong Kong experiences more frequent heavy rain. On average, around 30 tropical cyclones form yearly in the Western North Pacific and China seas, with around half of them reaching typhoon strength. From 1961 to 2020, the long-term average rainfall in Hong Kong was 704.2 mm (about 2.31 ft) with an average of 6 cyclones per year and wind speeds that reached up to 118 kilometres (about 73.32 mi) per hour. These tropical cyclones occur most often from May to November and are most frequent in September. The heavy rain and winds cause landslides, severe flooding, and the falling of trees and debris. Another relevant statistic studied by the observatory is the highest hourly rainfall from 1885 to 2023. The data suggest that the highest hourly rainfall record has been broken several times in the past few decades, as opposed to being broken only every four decades preceding the 1990's (Figure 19).

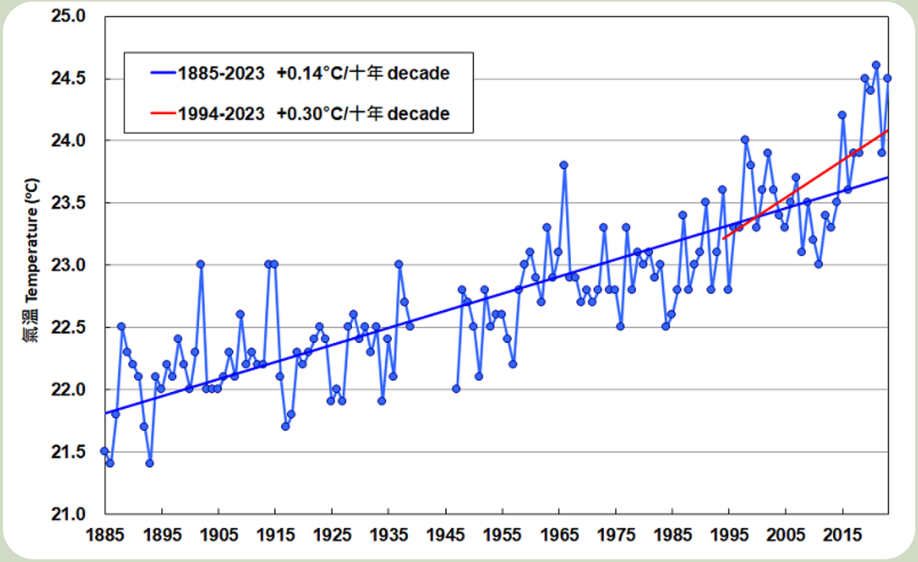


Figure 17 - Annual Mean Temperatures from 1885 to 2023 in Hong Kong, The Hong Kong Observatory

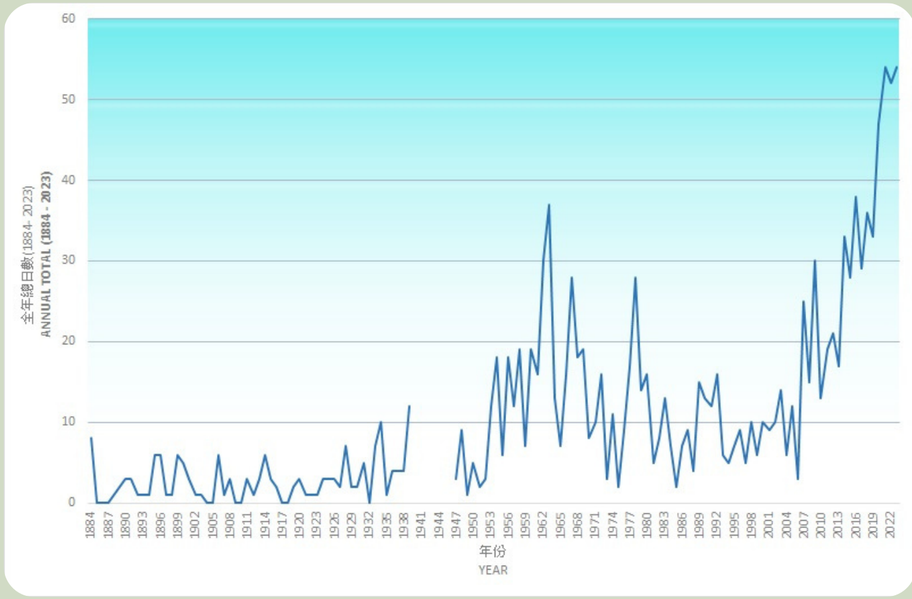


Figure 18 – Annual Totals of "Very Hot Days" (exceeding 33 degrees Celsius) from 1885 to 2023, The Hong Kong Observatory

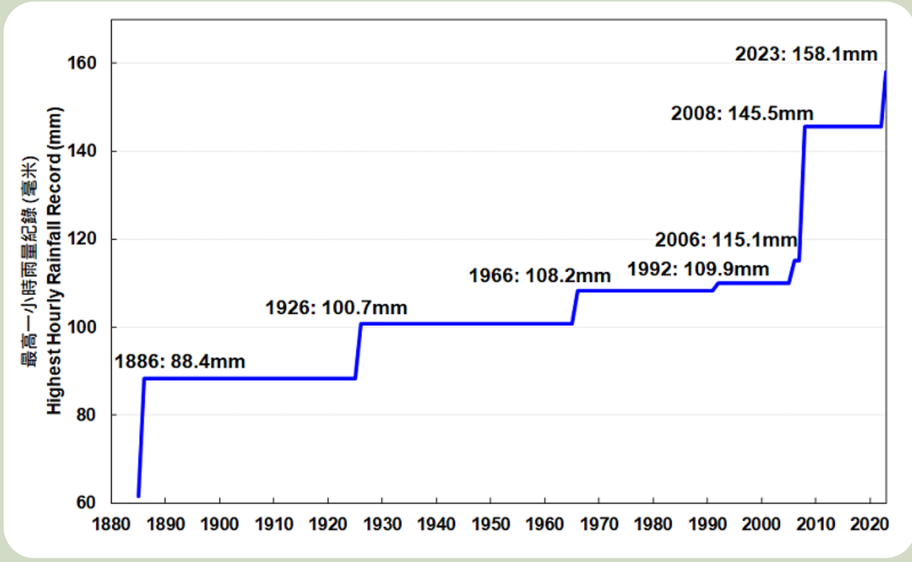


Figure 19 – Highest Hourly Rainfall Records from 1885 to 2023 in Hong Kong, The Hong Kong Observatory

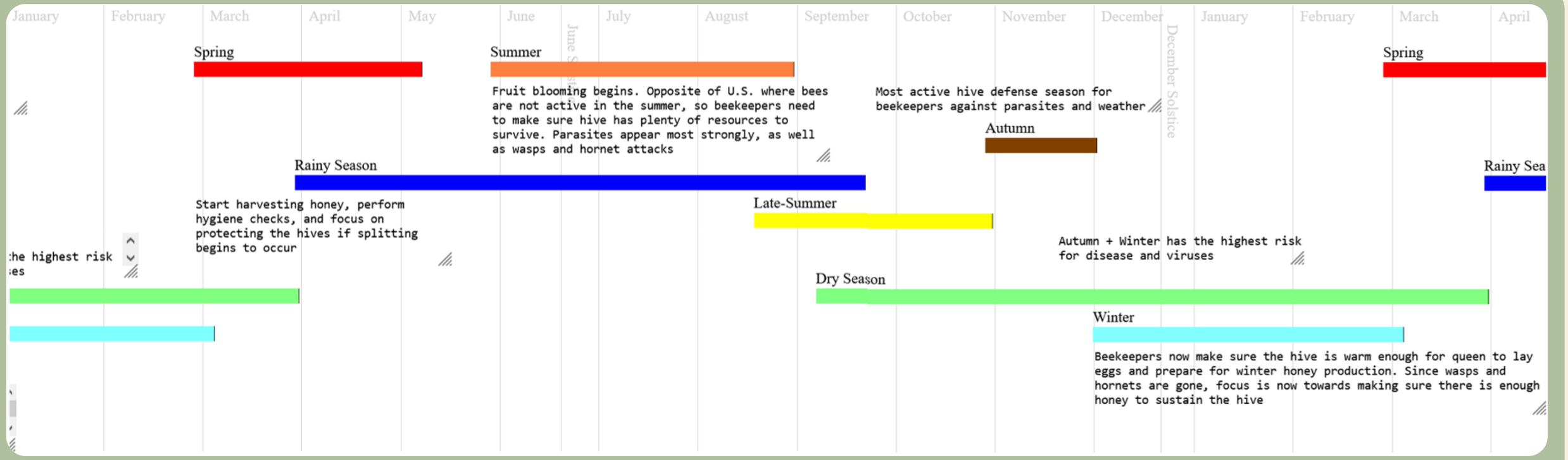


Figure 20 - Beetales Ltd. Seasonal Year Displayed Within CALENDARS Tool

Progress on Data Visualisation Tool

The second major objective of our project was to further develop the web application initiated by the 2022 New Zealand CALENDARS IQP (shown in Figure 20). In its initial state, the tool comprised of a simple calendar recording medium which sent data to a now offline database backend created by the 2022 New Zealand team. For the tool to be in a ready-out-of-the-box state for future IQP teams, we decided to better package the tool by allowing data to be stored in the user's own web browser. This allows future researchers to easily host the tool on their own platform and to easily store information gathered on their own devices without needing to establish an independent backend database. With the intent of hosting the tool on the CALENDARS Researcher's website, we also simplified the methods dealing with storing and retrieving data to allow for custom API and database support to be easily implemented.

Recommendations for Future Tool Development

For future additions to the IQP CALENDARS tool, our team recommends a complete overhaul of the User Interface (UI) of the tool as its current state makes data collection impractical for research usage; varying screen sizes when recording data can misalign saved calendars and inconsistencies between how different researchers record data makes for little to no standard of comparison. Even with qualitative data, it makes it difficult to draw any connections or conclusions between different seasonal mappings, especially in the presence of microclimates, as in our case. Our recommendation is to integrate a front-end framework (preferably in JavaScript such as React.js or Riot.js) that can more easily construct the UI into a standardized application for data input. We also recommend introducing the ability to select pre-filled calendar templates, such as the Gregorian calendar seasons, tropical seasons, or Solar calendar terms, so that researchers and/or individuals filling out their seasonal year can base their experiences on more traditional seasons if desired. We also highly recommend having multiple language options for the tool to provide the best accessibility for non-English-speaking users.

Comprehensive StoryMap Representation

The third and final objective of our project was to create a comprehensive ArcGIS StoryMap (Figure 21) representation of the information collected during interviews documenting the current and historical experiences of beekeepers in Hong Kong. Topics included in our site are information about our project, differences between the Eastern and Western honeybee, threats to the Eastern bee, role and explanation of different kinds of beekeepers, personal interview features, and our representation of the beekeeping seasons of Hong Kong. These topics are informed by beekeepers our project has interviewed. The relatively small sample size of our research has allowed our group to create detailed profiles and dedicate a section of the site to each location visited by our team. Common themes identified across interviews and website input from beekeepers are included.

An initial draft of the site was presented to two of our team's beekeeping contacts, Harry and Siu from Beetales, who shared their initial impressions as well as what information they thought would be helpful to add to this beekeeping resource. Both Harry and Siu discussed how there is limited online information and academic literature that focus specifically on the Eastern honeybee. Therefore, a section on the site about this species and its differences to the Western honeybee may be helpful for new beekeepers in Hong Kong. Harry also stated that it is important for the site to emphasize that bees are not the sole contributors to pollination: conservation should be inclusive of other pollinators such as wasps, moths, flies, beetles, and birds. The expanded CALENDARS IQP tool is embedded in our StoryMap so that individuals who visit the site can record their personal experiences and visualize how their practices compare to those described throughout the StoryMap.

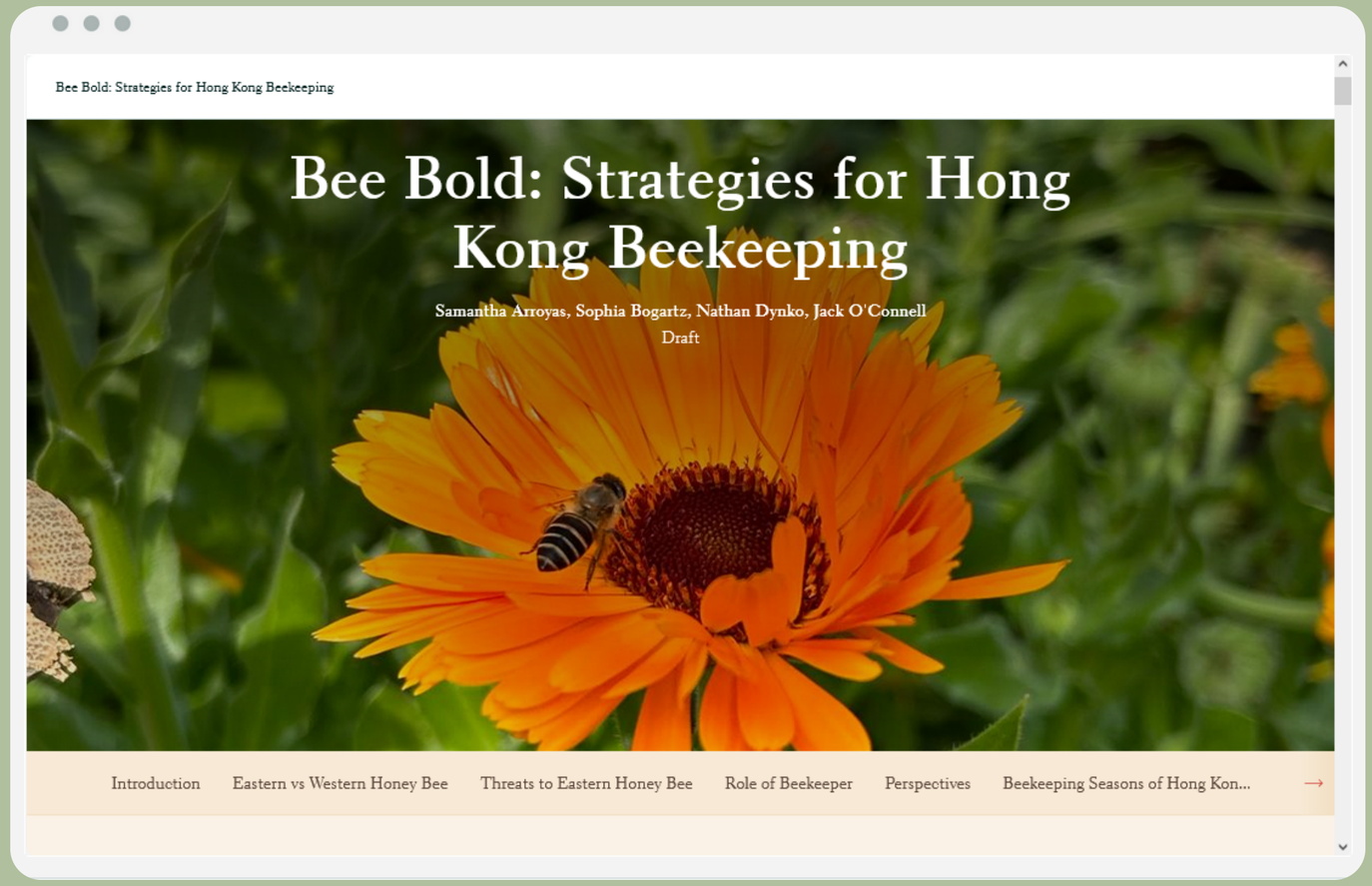


Figure 21 - Title Page of Our ArcGIS StoryMap Website

Conclusion

The produced seasonal representation of a typical year of beekeeping suggests that the identified seasons of beekeeping and association of specific tasks or events to each season closely align with the meteorological seasons: spring, summer, winter, and fall. The main points of interest in this aspect are that the beekeepers' perception of when they should complete different practices is dependent on the conditions of their immediate environment. Many beekeepers observed that the weather and temperature of their locations have been changing, and that this change is most significant within approximately the last ten years. All beekeepers shared that their practice has become more difficult in recent years, primarily due to the presence of more extreme temperature fluctuations, disease, and pesticide pollution - all of which are consequence of imbalances in the climate due to environmental change. All beekeepers asserted that Hong Kong is unique in its climate, geographic features, and biodiversity that can cause environmental conditions in relatively close locations to differ substantially. One difficulty of our project may be best encapsulated in a beekeeper’s statement from the Kadoorie Farm and Botanic Garden that all of the challenges regarding the environment are interconnected. This makes it difficult to pinpoint exact causes of change within the ecosystems where the beekeepers are located. The observations included in our project suggest a trend of increasingly severe challenges as a result of the changing climate and environments in Hong Kong. Some beekeepers interviewed shared that they are concerned for the future if changes in their environment continue to progress. Based on this understanding, our prediction of how beekeeping in Hong Kong will be affected going forward is that beekeepers will likely face the same challenges, but to a greater extreme.

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