Bachelor's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Social and Educational Sciences
Department of Geography

Oliver Ødegård

Investigation of pollinator diversity and daily phenology

A case study in Svelvik

Bachelor's thesis in Geography
Supervisor: Ursula Enzenhofer
Co-supervisor: Julia Wiel
May 2024

Cover photo - Anita Land

NTNU
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NINA
Norwegian Institute for Nature Research

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Preface

The following bachelor's thesis is written as a concluding assignment for my bachelor's degree at the department of geography at Norwegian University of Science and Technology.

During this semester, I have learnt a lot from delving into both spatial and technical data, as well as a great learning outcome related to the literature search. Great improvement in the usage of ArcGIS Pro and Rstudio has helped me on my path to widen my broad geographical research, as well as to investigate into one of the many possibilities that the field of geographical academic work can lead to.

I will use this opportunity to show my deepest gratitude to my supervisor Ursula Enzenhofer for great input in structure and visible presentation. Thank you also to Julia Wiel, for her tremendous co-supervising in both manoeuvring through many interesting topics, help with formatting of fieldwork data and ultimately the great support I've received to make this geographical thesis as good as possible.

My deepest gratitude also to all the people at NINA who provided me with valuable information about the topic and the previously conducted fieldworks is also in rightful honour; a warm thank you to Aubin Gillot, Helene Müller Haugan, Sondre Dahle and Joseph Chipperfield.

Oliver Ødegård

Trondheim, 14th of May 2024

Abstract

Global warming pose both threats and possibilities, as more land could become arable on high latitudes, for example orchards. Monitoring the pollinating insects will thus be of even higher importance in the future, and one of the emerging methods are acoustic monitoring. In this thesis, this acoustic method will be compared to more classical flight intercept traps and flower visitations, and the daily phenology at the location of research. The core findings relate to the fact that many parameters can be difficult to interpret, but by using a combination of the methods, a lot can be told of both species' abundance and richness, as well as the daily phenology at the fields.

Sammendrag

Global oppvarming utgjør bade trusler og muligheter, deriblant det faktum at nye landområder på høye breddegrader kan huse dyrkbar mark, eksempelvis frukthager. Overvåkning av pollinerende insekter vi derfor bli enda viktigere i fremtiden, og en av de fremadstormende metodene for dette kalles akustisk overvåkning. I denne oppgaven vil denne nye akustiske metoden bli sammenlignet med de mer klassiske fellene og overvåkning av bestøvningen, samt hvordan den daglige fenologien er på forskningslokaliteten. Kjernefunnene relaterer til det faktum at mange parametere kan være vanskelig å tolke, men det beste resultatet vil fremtones ved å benytte seg av en kombinasjon av de tre metodene. Da kan både artsforekomst, artsantallet og den daglige fenologien i frukthagene bli kartlagt.

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1 Introduction

To maintain the carbon footprint low, maintaining a self-sufficient food production in Norway is of great importance. This is done by increasing agricultural production, and by reducing the transport emissions. However, the rapid increase of extreme weather conditions poses significant threats to agriculture, and particularly to orchards. Different climatic conditions, like soil erosion due to heavy rain and freezing of the ground during blossoming can have big impact on the potential yield of fruits (Finci et al., 2023, p. 16). Given the changing climate, looking into the key elements of food production, such as pollinators, is of high importance to ensure success in the further production.

Therefore, the aim of this thesis will be to identify the factors contributing to the attraction and pollination of various fruit trees by examining the patterns of insect pollinators and the daily phenology of different species. Specifically, the research will focus on apple and pear production sites in Havnevik and Svelvik, located in Drammen municipality of southeastern Norway. This narrowed focus will enable a thorough exploration of the relationship between insect behaviour and fruit tree pollination within this specific geographical area.

This thesis is closely linked to Norwegian Institute for Nature Research's (NINA) APPLECORe project, particularly its subproject of BuzzyBee. This thesis contributes to do the background documentation of bee monitoring, comparing the results from the three methods deployed, as well as discussing the combination of the methods to answer critical questions about pollinators phenology.

The overall aim of the APPLECORe project is to address several limiting climatic factors affecting apple production in Norway. These factors include temperature variations, particularly frost nights in late spring and low temperatures during the last months of the years. Another factor that has emerged in the recent years, is the rainfalls ability to have potential of drastically alteration of the soil properties (Vujadinović Mandić et al., 2023, p. 1). All these factors have a big potential to alter the fruit production and are of high geographical relevance, but in this thesis, the focus will be on the biological aspect – the abundance of pollinating insects in the four fields of apple production in southern Norway. The main research question for this thesis will therefore be; *to see what type of the three methods used gives the most realistic picture, if the results are comparable, and how the daily phenology of the different pollinators was at the two sites of research during May of 2023.*

The first chapter of this thesis will provide some background for the research. Following that, a methods chapter gives insight to how the data was collected and how it is used in the context of this thesis. Furthermore, the results will be presented and discussed with presentation of limitation and suggestions for further research on the topic, before bringing it to an end with some concluding remarks.

2 Theory

2.1 Current situation

Due to Norway's geographical location, there is limited areas of which commercial apple cultivation is possible (Vujadinović Mandić et al., 2023, p. 1). The country's apple production represents the northernmost fruit-tree production in the world, with western Norway as one of the most productive areas. Another area which suits the needs for production, is Svelvik located in Drammen municipality in the southeastern district, as seen in Figure 1,

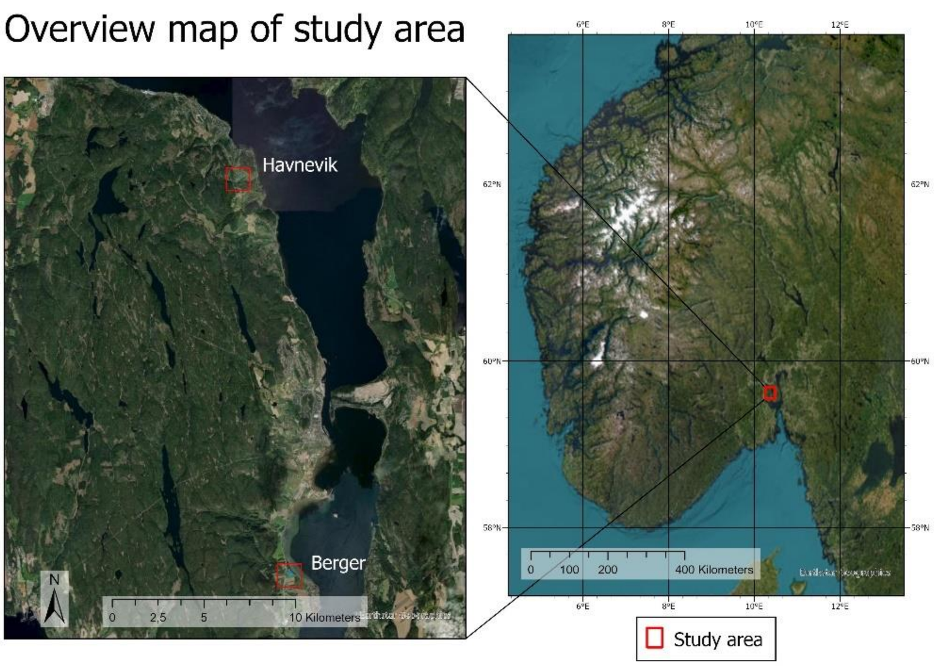

Figure 1 - overview map over Norway, with the two locations shown at left hand (Ødegård, 2024)

and is the location that therefore will represent the main area of study for this thesis (Gasi et al., 2023, p. 1). The earlier emergence of bud burst and flowering in the northern hemisphere and more specifically in Norway has been well documented (Nordli et al., 2008; Rivero et al., 2017; Woznicki et al., 2019). These external ecological factors, together with decreasing and fractioning of habitats and species interaction where there are usage of both managed and natural habitats, are affecting the biodiversity in the area (Holzschuh et al., 2011, p. 3444).

This is the case in Svelvik, and many of the other pome fruit production areas in Norway, and the world.

Certain studies have shown that securing effective and high density of pollinators in Norway, an increase in the number of beehives might be beneficial (Nogué et al., 2016, p. 12). Even though this is the traditional and convenient way to secure pollinations, a discussion of domesticated honeybees put up towards wild pollinators has been raised the last years. Honey bees are more often treated as manages pollinator species by farmers, compared to *Osmia cornuta*/*bicornis* and *Bombus* spp. (Leclercq et al., 2023, p. 8). A review on the importance of wild pollinators on apple production worldwide has stressed that the wild pollinators are the frequently more effective apple pollinator (Pardo & Borges, 2020, p. 1). This will be later investigated in this thesis. Additional, securing good habitats and securing viable populations of wild pollinators are completely in thread with the Norwegian governments pollinator strategy (Norwegian Ministries, 2018, p. 22). There has been a decline of managed pollinators observed across European countries due to climatic changes, exposure to pesticides, disease and lack of habitat (Breeze et al., 2014, p. 1194). And all in all, the domesticated honey bees' broad pollinator coverage has been discovered to be less effective that to those of the wild bee species (Garibaldi et al., 2013, p. 1608).

Biotic pollination of crops are of high importance, and studies around this topic has increased the recent years (Garibaldi et al., 2020, p. 664). The impact of biodiversity loss has resulted in an overall decline in bees and other pollinators. Different external pressures like land-use change, climate change and emergence of alien species also affects the biodiversity (Pardo & Borges, 2020, p. 1). Suitable habitats for bees in near presence of agricultural landscapes limits both species richness, species abundance and pollination efficiency. In addition, positive correlations has documented in amounts of semi-natural habitats and bee diversity (Sydenham et al., 2016, p. 961). Loss, degradation or fragmentation of habitat placed third in a questionnaire on greatest threat to pollinator populations on a world basis, beaten only by *Varroa destructor*, a parasitic mite attacking honey bees, and pesticides (Convention on Biological Diversity, 2018, p. 10). The need for more careful research around the topic of monitoring crop flower visitations in agricultural settings are of high importance, both to better understand the dynamics of pollinators and to improve and sustain crop production (Hutchinson et al., 2022, p. 300).

This thesis will primarily investigate how various methods of measuring insect abundance yield distinct results, aiming to identify potential differences among them. The three methods used in the area of study is the flight intercept trap (FIT), flower visitations and passive acoustic monitoring, with the latter one being the most recently put into the field biologist's toolbox. FIT has been in used regularly in forests and grasslands, and more recently also in agricultural landscape. Similarly to the PAM, it uses no attractant and can therefore be classified as a less biased observational method compared to other conventional methods and traps (Shi et al., 2022, p. 692). One of the early identified challenges with PAM was the time-consuming acoustic analysis. The extracting of biological information were based on manual analysis, performed by humans (Sugai et al., 2019, p. 20). In present day, arrival of big amounts of datasets and improvements of adaptable analytic software are improving these early problems in rapid pace. PAM are now used on growing fields, like conservation planning, behavioural and phenology and monitoring of species concerning ecosystem services providers like pollinators (Gibb et al., 2019, p. 181; Ross et al., 2023, p. 1).

2.2 Previous work on phenological studies

The knowledge on the consequences of phenological mismatch on ecological interactions, for example on pollinators and plants, are limited. There has been some indication that there might be an emerging problem with phenological timing, but in general the pattern of development seen because of global warming seems to be caught up by the biotic life. The reason for this is that insects and the plants they pollinate may use similar environmental cues to time the start of spring and the activity that follows (Kőrösi et al., 2018, p. 2).

There are few species needed to provide ecosystem services, whereas a big portion of crop pollination is provided by only 2% of bee species. Evidence has been lifted that the wild pollinating species that contribute to ecosystem services are quire robust to agricultural intensification, and can be easily be added to these systems with relatively small measurements (Kleijn et al., 2015, p. 4).

2.3 Rosaceae-family

The fruit production of apples and pears, both included in the family of *Rosaceae*, are dependent on cross-pollination from another species that flowers in the same time (Geslin et al., 2017; Stern et al., 2007). Thus, insects are inevitable important for carrying pollen and pollinating the individual trees. The genus *Malus* and *Pyrus* are both under the family of *Rosaceae.* As for the pear production, there has been a decline in the Norwegian pear, *Pyrus communis* L., the last 25 years. The main reason for this decline is the increased pressure from Asian and American import (Meland et al., 2021, p. 149). As for the regular apple, *Malus domestica*, it is one of the most important fruit crops globally (Pardo & Borges, 2020, p. 1).

In the Norwegian context, the always present climate change has a positive effect on the harvest of apples. From 1986 to 2016, flowering time for an average apple tree has advanced with 9 days (Ličina et al., 2024, p. 3). Additionally, a recent study showing areas of importance for apple, and the spatial distribution expiation of these favourable areas, gives way to a more prominent increase in future apple production at many areas throughout the country, including eastern Norway (Vuković Vimić et al., 2023, p. 13).

2.4 Pollinators

Both managed honeybees and wild pollinators are contributing to the pollination of agricultural crops. Additionally, many crops will produce a better yield when located in an area with a higher degree of wild pollinators (Bakken et al., 2023, p. 40).

There are numerous non-governmental organizations in Norway that are working with biodiversity of pollinators and raising the public awareness of the importance of species. The "National pollinator strategy" released in 2018 access the need for ensuring continued diversity of wild bees and other pollinating insects (Norwegian Ministries, 2018, p. 4). Common for all pollinating insects are the need for blooming plants. To ensure good viability for pollinators, mapping the habitats and getting grasp of under which conditions they thrive is of high importance (Norwegian Ministries, 2018, p. 25).

As a follow-up of this aforementioned strategy, an action plan got published in 2021 to present what action the government will implement to ensure the best possible lining conditions for the wild pollinators in Norway. This plan is to be set in action in 2024, and there are a number of relevant points for orchard farmers in Norway (Klima- og miljødepartementet, 2021, p. 65). The plan also mentions that wild pollinators deliver ecosystem services of great importance and high economic value (Klima- og miljødepartementet, 2021, p. 15)

As mentioned above, the managed money bee species, *Apis mellifera,* is the most important pollinator worldwide. But on the other hand, wild pollinators are more important to both biodiversity and to have a fully functional orchard in the word generally and in Norway specifically. Increasing of insect pollination in apple orchards have previously shown an improved fruit set and yield (Garratt et al., 2014, p. 35). Therefore, this article will focus on which species have been pollinating at different locations and at different temporal intervals at the location of study.

Climactic factors affect pollinators in different ways. Norway is a country with a prominent long coastline and are situated in a geographical location where air masses from the cold arctic encounter warmer, humid air from the south. This gives way to large frontal systems to be created, and thus major rainfalls occur regularly, especially during fall and winter, but periodically throughout the whole year (Lutz et al., 2020, p. 1). This in turn affects the pollinators, and generally their activity is documented to decrease during periods of downpour. Additionally, the return to their respective beehives after foraging pollen also tend to decrease with precipitation (Lawson & Rands, 2019, p. 563). An extensive literature review of early articles in the field of acoustic monitoring mentioned a few recommendations of further works on the topic, some of which will be pursued in this work. This includes factors regarding the environment, for example humidity and temperature (Ross et al., 2023, p. 967).

2.5 GIS © and spatial data

The Havnevik site, which is the northern one of the two, are the site with less intensive agriculture. There are fewer trees per square meter, and less agricultural area nearby. A big area in direct proximity is a coniferous forest, and this site is also accompanied with semi-natural habitats along private roads. This could indicate that there might be a higher diversity of pollinators.

At the southern site, Berger, there is a higher degree of agricultural production, and thus more anthropogenic in its appearance and composition. When orchards drape at all sides of our research field, the landscape become much more homogeneous. If it were to follow the general rules of pome fruit production, we would here see a more prominent activity from the managed honeybee, *A. mellifera.* In Figure 2, the two areas are introduced, with the blue polygon field representing the borders of where the data were collected.

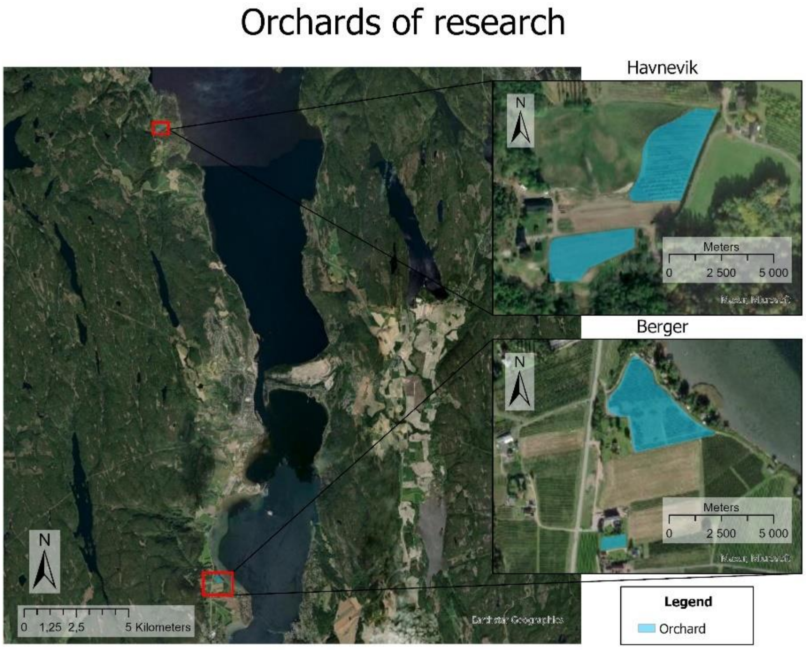

Figure 2 - showcase of the two areas, Berger and Havnevik (Ødegård, 2024)

2.6 Collector methods

The data provided in this thesis has been captured using both visitations, traps, and acoustics. This part will include an introduction to the three methods used in the area of research and provide the reader with an overall understanding of the positives and negatives of the different methods. In table 1, the different advantages and challenges of the three methods are presented in a simplified manner.

Method	Advantages	Challenges
Flight intercept traps	Not time consuming (no need for constant surveillance); easy to set up; weather resistant	Catches non-pollinating insects
Flower visitations	Accurate description about pollinator; certainty of no other pollinator has visited before	Energy demanding (require fieldworkers); abrupt stops if external factors come up; human errors (misses pollinator visits)
Passive acoustic monitoring	Low cost; non-intrusive and non-destructive; continuous and omnidirectional monitoring; large and fine spatial scale	Human disturbance and activity; signal pre-processing; isolating sound of interest; suppression of noise

Table 1 - Advantages and challenges of the tree methods used at the location

2.6.1 Flight intercept traps

The flight intercept traps (FIT) used in the research project can be classified as a modified window trap. The trap itself consists of a top collector, a flight battier and a bottom collector. The top collector's purpose was to collect *Hymenoptera*, and the bottom collector were supposed to catch other flying insects. Earlier studies has shown this type of trap to be very effective, with both the top and bottom collector (Knuff et al., 2019, p. 1822). The flight barrier in the middle was serving as an omni-directional flight barrier for the insects, and when the insect encountered the barrier, they would either fall down into the bottle with water or fly upwards. The FIT is proven to be effective in capturing a diverse range of taxa, and thus being a suitable measure of assessing biodiversity (Knuff et al., 2019, p. 1820). At Svelvik in 2023, in time for the registrations of this fieldwork, the traps were filled with soapy water to secure the pollinators from escaping.

The purpose of these FITs is the desire to randomly attract and catch insects, in contrast to other commonly used bee traps like pan traps and vane traps. These types of traps use colour to attract bees. During the fieldwork, there were some deviations from the expected results. The top collector caught very few insects, proving that just a selection of the pollinators in these orchards would fly upwards when encountering the barrier. Higher success rate was encountered with the bottom part, and a wide diversity of pollinators were caught and registered. In Figure 3 an example of the FIT used is presented.

Figure 3 - Flight intercept trap used in Svelvik (APPLECORe)

2.6.2 Passive acoustic monitoring

Passive acoustic monitoring (PAM) are now used in a wide diversity of fields, like conservation planning, behavioural and phenology and monitoring of species concerning ecosystem services providers, like pollinators (Gibb et al., 2019, p. 181; Ross et al., 2023, p. 1).

One of the early identified challenges with PAM was the time-consuming acoustic analysis. The extracting of biological information were based on manual analysis, performed by humans (Sugai et al., 2019, p. 20). In present day, arrival of big amounts of datasets and improvements of adaptable analytic software are improving these early problems.

Advancements in a broad spectrum of technologies in the field of technology and computational processing have widened the possibilities for more effective monitoring. Additionally, the collected data can be analysed in an efficient manner (Heise et al., 2020, p. 1).

PAMs ability to monitor multiple taxonomic groups at the same time, presents researchers with a new academic weapon. Understanding the complex ecosystems can be done in a much more efficient manner if an extensive catalogue of fine resolution data for phenology were to be developed. There are however multiple challenges with this monitoring technique. The propagation of signals will be recorded in various ways, depending on habitat structure, weather and strength of signal given. Furthermore, unwanted noise from weather and anthropogenic sources compose some of the challenges (Ross et al., 2023, p. 962).

The data used in this thesis uses the scientific language of Mel Frequency Cepstral Coefficients (MFCC). These are coefficients that allows recognition of sound with limited data and were developed in the 1980s. The process of the PAM includes machine learning of different species, in-field monitoring of the insects, followed by K nearest neighbour (KNN) classification to recognize the correct insect (Marquet, 2023, p. 9).

The collection of the PAM data was done using audiomoths, which are small microphones used to measure biodiversity and the environment, in a reliable and efficient way (Hill et al., 2018, p. 1). These were then placed in different location within the two localities of the greater Svelvik area. 4 of the audiomoths were placed in Havnevik, the northern orchard, and 5 in Berger, the southern orchard. In Figure 4, the audiomoth is shown mounted by one of the fruit trees. At Berger, there were insect hotels and flight intercept traps already installed, so that was the natural area of placement. At Havnevik the fruit trees themselves were used as attachment points (Marquet, 2023).

The use of machine learning for large scale bioacoustics monitoring of Norwegian *Hymenoptera* has been confirmed to be possible, and the usage of KNN has been documented as successful, as well as other multiple classification approaches (Øverli, 2021, p. 25). Additionally, a recent published article has shown great progress in the field of monitoring species activity and diversity. The possibility to detect the presence of *A. mellifera* and separate their sound from other wild pollinators, as their wingbeat sounds were on average lower pitched (Rodríguez Ballesteros et al., 2024, p. 6).

Figure 4 - Audiomoth used in Svelvik (APPLECORe)

2.6.3 Flower visitations

The visitations surveys were conducted by several people, working on the project in the spring 2023. In preparation, the people responsible for the project had put pollinator exclusion bags (PEB) around the flower heads before the blooming, to ensure no visits from pollinating insects were top happen unsupervised. When the fieldworkers went to the site for the first time, the PEB were removed carefully so that the flowers were not damaged. Then the visitation-period could start, and the workers monitored the tree from a safe distance, so that they would be able to recognize any activity, but not scare away any visitors. The visitations were supposed to last for exactly one hour, or it ended earlier if all the prevailing flowers got pollinated earlier, the farmers needed to spray the field with pesticides or other external factors. Active methods like these are reliable and extensive, when flower visits and visitation rates are to be determined (Hutchinson et al., 2022, p. 300).

2.6.4 Others

In addition to the collecting methods listed above, there were drones present at the field site. This was done to get an overview of the orchards and the workers at the time of study but were provided to be futile as a method for recording pollinator activity.

3 Methods

3.1 Study sites

The dataset used in this thesis consists of numbers gathered in using the three forementioned collection methods, including flight intercept traps, flower visitations and passive acoustic monitoring. The data were collected between the 12th of May to the 31st of May 2023, by several researchers from NINA. Various different species were identified, including the anthropogenic introduced *A. Melifera*, as well as different species of wild pollinators in the genus of *Osmia* and *Bombus.*

The four orchards, at two sites, that has been the subject of monitoring are both located within the municipality of Drammen, with approximately 13 km north to south of each other. There is a distinct difference between them, whereas the northern site represents a more natural orchard. The southern site on the other hand, has a more manufactural appearance, with higher yields in apples and pears than its northern counterpart.

3.2 Data

The data acquisition setup was collected with small acoustic microphones, called Audiomoths, and in the dataset used here, it is converted to represent the daily phenology. This was done by extracting the information used in Marquet's (2023) report from a Python script and transcribing it to Rstudio. Looking into the overall activity of the insects, it has been calculated to be greatest between 02:00 and 08:00 and between 13:00 and 21:00, as shown in the report (Marquet, 2023).

For the FIT, the traps were collected every other day, by researchers in the field. For the pollinator exclusion bag visitations, there are data from almost every day, but the structure of this is difficult to compare directly. This is because the visits from the different pollinators are documented only once, with each pollination being the one and only for each flower. This will be discussed later. Both of these datasets was read into Rstudio, and further formatted there.

The weather data was downloaded from "Norsk klimaaservicesenter" as an xlsx file, and further manipulated in Rstudio, to ensure better readability (Meteorologisk institutt, 2024).

4 Results

The data from the methods part have all been extracted from earlier conducted fieldwork done by researchers at NINA, under the APPLECORe- project. The PAM dataset was extracted from Marquet's dataset, and then further adjusted to fit the other datasets in Rstudio. In this part of the thesis, the results will be presented.

4.1 Data from the Passive Acoustic Monitoring (PAM)

4.1.1 Havnevik

There was two Audiomoths placed out in the northern site, Havnevik, this first one given the name of "Apple2". This microphone had the highest recording rate, giving the result of only one day that the recording did not go as expected, that day being the 21st of May.

As the bar graph in Figure 5 shows, there is a rather continuous flow of bumblebees throughout the period. 16th, 23rd, 25th and 26th resembles the 4 days of increased activity, but overall, there is an evenly distributed pattern. For the wasp, there are no such pattern. Here it is clearly visible that the 16th and 17th are days of increased activity, and the rest of the period it is rather low, with no consistent pattern to be seen. For the domesticated honeybees, has two days identified as outliers, with the 16th and 23rd being days of very increased activity, approximately 3100 and 2250 recordings on the two days respectively.

Calculating the average recordings per day shows 662 for bees, 478 for bumblebees and 255 for wasps.

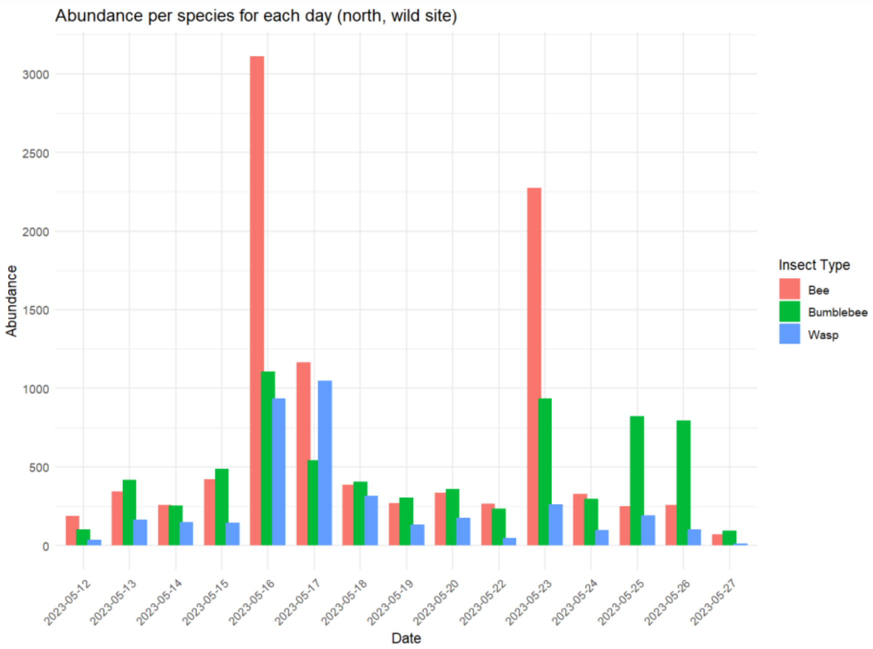

Figure 5 - abundance per species for each day, at Havnevik (Apple2)

The second Audiomoth were also placed at Havnevik. This microphone was given the name of "Apple 4". This recording had a hiatus of three days, with no data being collected from the 21st to the 23rd of May. Like the other Audiomoth placed at Havnevik, there are some outliers to be identified. The 15th of May, as Figure 6 shows, had a very high recorded number of bees to visit the area around the microphone.

Calculating the mean recordings per group each day, the results show 355 for bees, 175 for bumblebees, and 94.3 for the wasps.

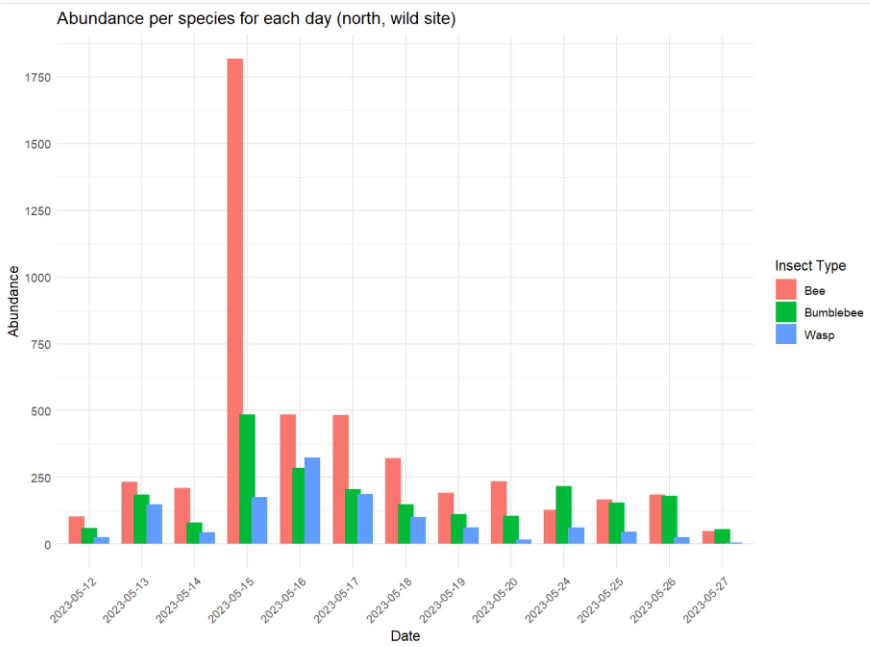

Figure 6 - abundance per species for each day, at Havnevik (Apple4)

4.1.2 Berger

At the southern site, the site of much higher anthropological or industrial, character, there wase placed Audiomoth. This microphone was given the name of "Apple 6". At this site there were a continuous recording throughout the period of investigation.

In the bar graph in Figure 7, there can be seen a distinguishing different pattern from the northern site of Havnevik. In summary there are less recordings of insect activity, with wasps and bees having a more closely resemblance in recorded sounds, at least in the first part of the recording time. Bumblebees have an apparent less degree of activity here, with 50 to 200 recordings per day.

As for the mean recording of activity per day, the numbers are 326 for the bees, 110 for bumblebees, and 277 for wasps.

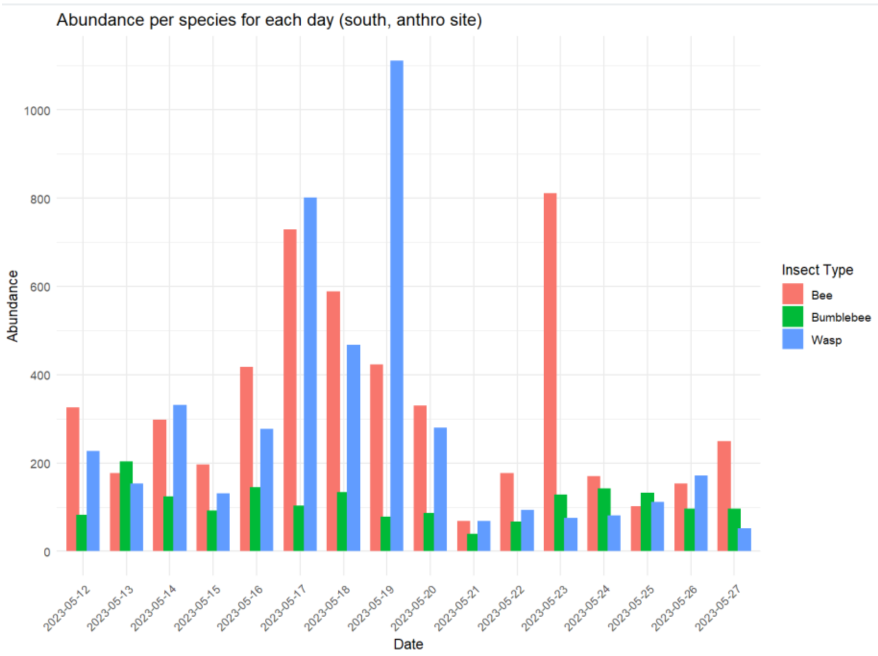

Figure 7 - abundance per species for each day, at Berger (Apple6)

4.2 Results from the visitations

In Figure 8 the daily phenology of pollinators is presented, by using the visitations data. ØBeA represents all the observations recorded at Berger, the southern more anthropogenic site. Here, there were 40 fruit trees to be observed at the whole Berger area, and 6 of these were at the southern orchard, which only had pear production. ØHaA on the other hand represents all the observations at Havnevik, the northern more natural production site. In this area, 5 of the visitations were in the southern field in Havnevik, and 12 were in the northern field, making it a total of 17 trees.

Looking at these results, the registrations are relatively even throughout the period. Berger has a stable recording, and Havnevik, where the first visitation was at the 22nd, had 3 days of high activity, and the rest at around 3 to 4 visits.

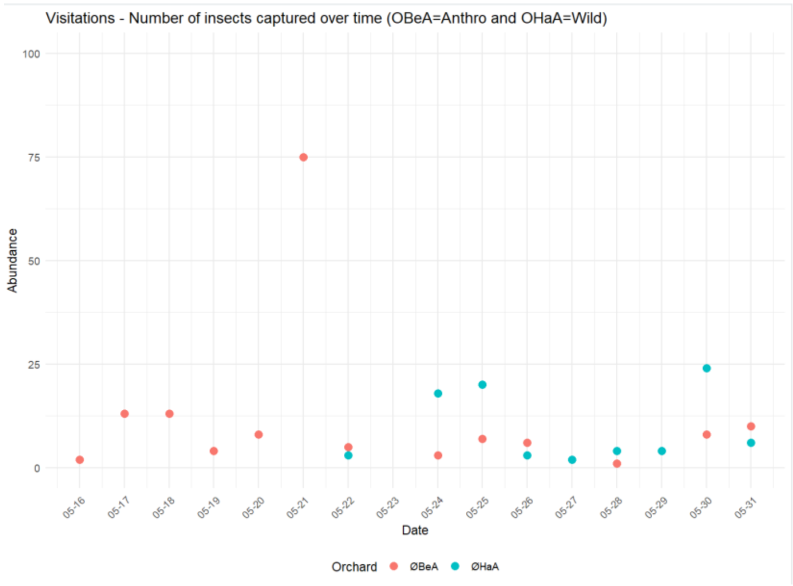

Figure 8 – Visitations; number of insects captured over time, both locations

4.3 Results from the flight intercept traps

As for the FITs, the grouping is a little different, and these results are presented in Figure 9. In these results, the two orchards at Berger are grouped into ØBeA and ØBeP, whereas ØBeA are the northern of the two fields with apple production, and ØBeP represent tree FITs located in the southern field, near the pear production. On the other hand, the same figure ØHaA and ØHeA both represents the norther, more natural production area, which only has apple production. Four of the FITs at Havnevik were located at the southern field, whilst there were five FITs at the northern field. These recordings are interesting and have a drastic increase towards the end of the season. Further comments on interpretation will be in discussion prat.

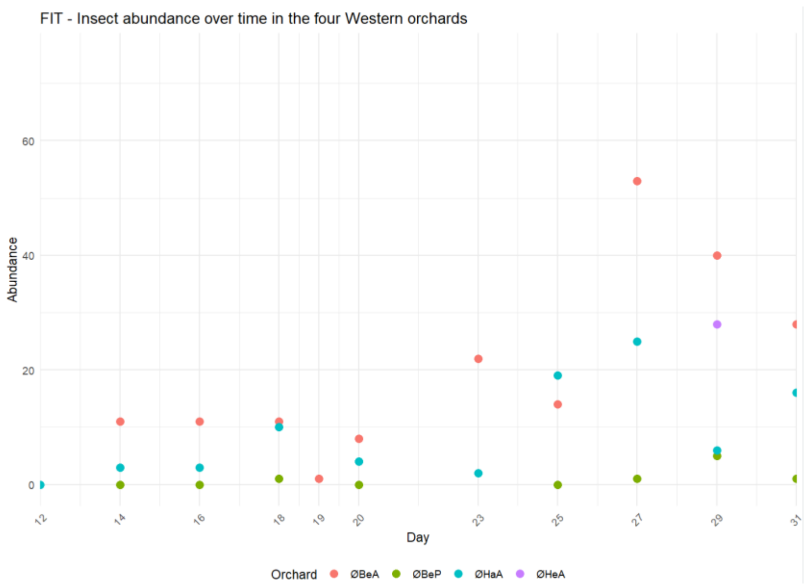

Figure 9 - FIT; abundance over time, at the four orchards

4.4 Weather data

In Figure 10, the precipitation, minimum-, middle-, and maximum-temperature from the Knem weather station in Svelvik are presented. The data was downloaded from Seklima, delivered by "Norsk klimaservicesenter", a subgroup of the Norwegian meteorological institute (Meteorologisk institutt, 2024). This is included in the thesis to possibly see if there are any connections from the pollinator abundance, and the weather during the timespan of the fieldwork. The graph shows relatively stable temperature and precipitation measures, with middle temperature ranging from 9 to 16 degrees Celsius, with the warmest days being at the end of the month.

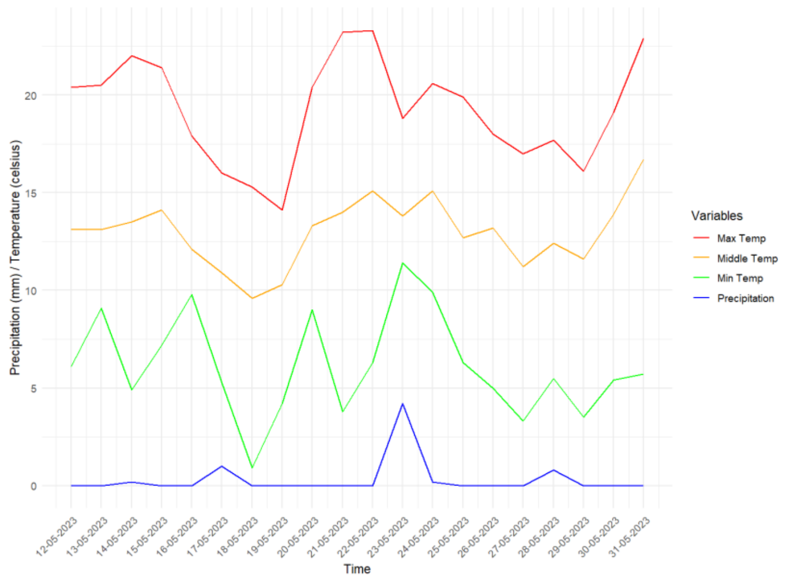

Figure 10 - Weather data from Knem weather station (Svelvik) from 12th to 31st of May 2023

5 Discussion

In this discussion part, there will be a division into two sections. First, the results will be discussed with a focus on the different sample methods, and further along the results will be interpreted in a more isolated manner, as to see if there are any possibility to see changes in the daily phenology.

5.1 Sampling methods

With the PAM, there is generally very big amount of data collected. As this type of monitoring is sampled in a way that correlates each sound registered and further classified with the KNN classifier, there will be a distinct difference in how the samples look in the final stage, as figure 5, 6 and 7 clearly shows. Although using acoustic monitoring is a very effective and low-cost way, the data collected says little about what insect is pollinating, but it gives a great idea of the abundance of each group. The Audiomoth at Berger and one of the two Audiomoths at Havnevik (Apple2) recorded at the day of rain, and at both locations the bee activity was one of the highest recordings, and one of the most numerous recordings of bumblebees at Havnevik at that day. This is in contrast to what earlier research would suggest.

The FITs are a widely used method as discussed earlier, and it also got very representative results in this research. As for the Berger area with pear production (ØBeP in Figure 9), there are very little data, with only two days with samples in the trap. This is probably due to the limited spatial area of the orchard, being much smaller than the three other areas of research, and thus no pollinators were caught during the first period of the fieldwork. Further on, there is a clearly visible trend that shows a higher abundance at Berger over the course of the time of monitoring. As this location is the more anthropogenic if the two locations, this is partly as expected. With more fruit trees available, there would in theory also be more pollinators out and about, and thus also a higher chance of more insects to fly into the traps, as we see here.

As for the visitations, there is a rather different pattern to be observed. As there has been people gathering in data of which species has pollinated the actual plant. This means that this method is describing the species richness in a better way, and not so much the species abundance. The Havnevik site shows a clear and obvious increase in pollinator activity on the 24th, 25th and 30th of May, of around 20 registrations. This could be due to either weather conditions, as there had been a day of rain at the 23rd, and more stable weather conditions the following days. It could also be due to intensified occurrence of researchers at that site during those days. At Berger, there is a more even distribution of pollinator activity, with around and just under 10 registrations at most of the days. The exception to this is the 21st of May, being one of the warmest days of the period. The temperature effect could have been one of the reasons. It could be due to increased activity for the pollinators, or even maybe increased activity by the researchers themselves. The increase in temperature leads to blooming of the flowers, which in turn makes the pollinators more active. At this point, they will be out and foraging, and the fieldworkers will finally be able to observe them in a much bigger degree.

5.2 Temporal fluctuations in pollinator activity

One of the main aspects of this thesis is to investigate in what degree the temporal changes during the season of pollination is observed. In general, it is difficult to see a strong pattern of which pollinators are the most prominent. For the acoustic data, there are a clear for the recordings that “Apple 4” and “Apple 6”, which are representing respectively Havnevik and Berger, has bees as the most recorded pollinator throughout. At “Apple 2”, which has its placement in the northern orchard of Havnevik, the results show a bit of a different pattern.

Even tough the bees have the highest average recordings per day, it is here visible that the bumblebees have registered higher recordings on 8 of the days. Bumblebees are one of the important wild pollinators crucial for the biodiversity, especially in terms of maintaining the wild flora that spreads around the landscape.

Keeping to the acoustic data, taking the wasps into account produces some interesting results. They have the least registrations at all the Audiomoths, but at Berger ("Apple 6"), they come close to the number that the bees have. As Berger is the location of heaviest fruit production, this is quite interesting. One of the hypotheses would be that the kept bee, *A. mellifera*, would pose the most recordings here, unlike to that evenness with the wasps that the results clearly point to. Although the wasp activity only outperforms the bees at some of the days, the high activity still is noticeable. One other interesting aspect is that there is a clear pattern of more activity during the first half of the study period for all the pollinators at Berger, and the wasps shows a peak on the 19th of May, with prominently less activity at the second half of the period. This could be due to the early warm period at the start of May, and thus could have led to the blossoming and therefore a high degree of activity at the start, with a decrease in activity later.

The temporal pattern for the FIT is quite interesting, even more so than with other two methods. Here there is a clear trend with an increase in pollinators acquired in the traps after the 23rd of May. The only exception is the smallest pear field at Berger (ØBeP), which has few catches all the dates, but the 29th represents a record high, with 5 pollinators collected. As for the other two bigger fields, at Berger and Havnevik respectively, there is a substantial increase. This might be due to the aftereffects of the little rainfall that occurred, giving a new spring for some of the pollinating insects.

As there has been used different methods to produce these results, getting continuous results with easily interpretable conclusion shows to be a difficult task. This is a problem met by many nature scientists, as data integration from ecological sources have no one single source. The challenging aspect of observing nature with different parameters and creating one big picture are seen throughout this thesis.

5.3 Sources of error

Due to the way the data was structured, and the amount of manipulation done in Rstudio, there might have been some loss of data. Avid use of Norwegian letters (specially Ø) throughout all the different files, made the code not possible to be compiled due to lack of readability in Rstudio. Additionally slight differences in the way localities and observations were written in the excel documents made the cleaning of the data in Rstudio difficult.

5.4 Further research

The initial thought was to correlate PAM with the other, manual methods, but since the PAM data from Marquet's report only were grouped in bees, bumblebees, and wasps, this became problematic. To further accomplish this research, using the recent research of Roderíguez Ballesteros et. al. (2024), the different species could be recognized using the acoustic data. This could give an even more accurate representation of the activity in the field, related to both the honeybees and other wild pollinators.

6 Conclusion

Although there a growing interest in the field of acoustic monitoring to record ecosystems and the activity within them, few scientific articles have been published regarding the comparison and effectiveness of the monitoring, related to other classical measures of biodiversity. This thesis has investigated the methods of acoustic monitoring, intercept traps and visitations, used in-field at two localities in Svelvik. The results have shown some tendency of compatibility, but given the different parameters there is some difficulties.

What can be interpreted by the results and discussion with great certainty, is that the visitations do a great job in assessing species richness and abundance, but only at a few temporal intervals. PAM, however, is a great measure for phenology over time, but only at higher place in the taxonomical hierarchy that for the other methods. It also comes short in describing if the pollinators assist in pollination or not. The same goes for the flight intercept trap, but this method is great for assessing species richness, and gives an idea of the abundance over time. To answer the main research question, a combination of the three methods in would give more thorough information about both richness and abundance, which in turn could enable the opportunity to get more details of the daily phenology of the pollination.

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