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The Use of Products with a Monitoring System for Remote Bee Detection in Beekeeping in Czechia

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Abstract

The use of modern technology is becoming part of both industry and agriculture. These technologies can also be used in beekeeping, where they can help to monitor the operation of the hive remotely. Beekeepers can remotely monitor the weight of their hives, their temperature, humidity, and other parameters. The aim of this paper is to map the beekeepers in the use of products with monitoring system for remote bee detection in beekeeping in Czechia. To map the issue, qualitative research using semi-structured interviews was conducted with beekeepers, manufacturers/providers of smart devices in beekeeping, and other entities involved in beekeeping. The findings showed that the interest of manufacturers and sellers to offer these smart devices is significant, but the interest of beekeepers is rather less, due to e.g., the purchase price, weaker IT knowledge, traditional beekeeping practices, higher age of beekeepers and the joy of being personally with bees. The novelty of the paper is not to look at the provision of ICT in beekeeping from a technical perspective, but from the perspective of users (beekeepers) and manufacturers of these technologies. Through interviews with beekeepers as well as others in the apiculture sphere, a comprehensive view of the issue is developed. Moreover, this is the first piece of research on this area in Czechia. .

Keywords

Precision beekeeping, precision apiculture, ICT in beekeeping, monitoring systems for remote bee detection, hive scales, Czechia.

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Introduction

Beekeeping is one of the oldest human activities on Earth and has many benefits for us. The importance of bees lies not only in the fact that they produce biologically valuable and beneficial substances for human health - honey, pollen, propolis, royal jelly, bee venom and wax, but mainly due to the fact they monitor the quality of the environment and ensure pollination of most crops and wild vegetation. Both family income levels and food security may be enhanced via beekeeping (Gratzer et al., 2019).

As in many fields, in beekeeping today we can also encounter advanced technologies that can monitor the hive remotely. Although many beekeepers still do things traditionally, namely manually, there is still more significant scope for the application of information and communication technologies (further as ICT). ICT can help beekeepers with implementation of automatic or semi-automatic solutions for bee colony remote monitoring, apiary record making and other actions (Zacepins et al., 2021). Apiaries are frequently situated some distance apart, this entailing a high cost to reach them, so such technologies can alleviate travel costs when used alongside more traditional, physical checks made periodically in person (Alleri et al., 2023). In scientific papers, among beekeepers or other and other bee specialists, we can encounter various labels for IT tools and solutions that can be used in beekeeping, including monitoring systems for remote bee detection. There are many different designations for the potential use of ICT in beekeeping including Precision Beekeeping, Smart Beekeeping, Precision Apiculture, Apiculture System, Honey Bee Monitoring, Smart Hive or Connected Hive. In this paper the designation precision beekeeping (further as PB) is used. PB is defined as “an apiary management strategy based on the remote monitoring of individual bee colonies to minimise resource consumption and maximise the productivity of bees” (Zacepins et al., 2015).

The issue of precision agriculture has been the subject of much research, which includes the area of PB. The use of sensor technology has changed a lot and its use in bee research and general beekeeping is becoming more widespread (Meikle and Holst, 2015). Beekeeping is an important part of agriculture with scattered locations that require monitoring of animals on a continuous basis (Catania and Vallone, 2020). Most of the studies and papers focus on the evaluation and creation of remote bee monitoring systems from a technical point of view, which is, of course, very beneficial for beekeepers, but there is also a lack of beekeepers' perspectives and their experiences, i.e., what they prefer and why, what benefits they see and, on the contrary, what are the problems when using these products.

There are very few papers that focus on beekeepers in their research part. Those that do include, for example, the papers by Zapacins et al. (2021) or Wakjira et al. (2021). The research by Zacepins et al. (2021) surveyed beekeepers in collaboration with the Latvian Beekeepers Association and investigated the status of PB in Latvia, namely in importance in use of precision tools and types of tools in beekeeping practice. Only the beekeepers' perspective is presented here, the perspectives of other apiculture entities are missing. Also, in the research reported in Wakjira et al. (2023), the perspective of beekeepers was important for the next steps in smart apiculture management services. They identified and described user requirements and started "a collaborative design thinking process to produce conceptual design solutions and low-level prototypes for essential products around the decision support system and the advisory support service for beekeepers". The third paper, which partly touches on the problem examined in this paper, is research by Alerri et al. (2023). This paper aimed to prepare a systematic review of the current state of PB and to draw implications for future studies. They prepared the research in January 2023, where the Scopus database was used taking into consideration title, abstract and keywords connected to PB. They found 201 papers, which they reviewed. Firstly, internal parameters of the hive were taken into consideration, in turn divided by weight of the hive, internal temperature, relative humidity, flight activity, sounds and vibrations, and secondly, external parameters in turn divided by wind speed, rainfall and ambient temperature. Alerri et al. (2023) also mapped other areas, such as possible undesirable effects of the use of sensors on bees, economic aspects, and applications of Geographic Information System (GIS) technologies in beekeeping. The country of origin of the first authors found in the Scopus database was also utilised by Alerri et al. (2023), considering the geographical location of the publication. Most publications originated from Latvia - 28 papers, followed by the USA with 26 papers, Germany with 20 papers, Italy and the UK with 11 papers. No first author of the publications found in Scopus was from Czechia or the Slovak Republic.

To investigate the issue of monitoring systems for remote detection of bees, we used Products for Remote Monitoring (or PRM for short), a combination of surveys with beekeepers, manufacturers/suppliers of ICT for beekeeping and other beekeeping experts and apiculture entities within Czechia were prepared so that the issue was processed from a comprehensive perspective. Therefore, the aim of the paper was set as follows: The aim of this paper is to map the interest of beekeepers in the use of products with a monitoring system for remote bee detection in beekeeping in the Czechia. The mapping of beekeepers' interests is divided into finding out who the beekeepers using PRM are, what benefits they perceive from PRM and what areas are slowing down the implementation of PRM.

The novelty of the paper is not to look at the provision of ICT in beekeeping from a technical perspective, but from the perspective of users (beekeepers) and providers of these technologies. Through interviews with beekeepers as well as other parties/entities involved in bees, a comprehensive view of the issue is developed. Moreover, this is the first research on this area organised in Czechia.

Literature review

Czechia and beekeeping

The first mention of beekeeping in the Czech lands can be found in chronicles dating back to 993. Various groups of beekeepers and processors of bee products were also established here. One of the most important achievements was the issuing of a patent on the keeping and protection of bees by Maria Theresa in 1775. The first major beekeeping association was founded in 1872, initially comprising 10 beekeeping associations. This association was named the Czech Beekeepers' Association in 1970 (Bee Shop, 2023). The Czech Beekeepers' Association has more than 54,000 members and 203 youth beekeeping clubs. This number represents 98 percent of all beekeepers in our country. Thus, Czechia is one of the countries with the highest organisation of beekeepers in the world. Czech-organised beekeepers keep 573,676 bee colonies (including separations). This is 97% of the total number of bee colonies registered in the Czechia (Český svaz včelařů, 2023).

According to Václav Krištůfek from the Biological Centre of the Academy of Sciences of the Czech Republic, Czechia is the fourth most bee-dominated country in the world, with over 700,000 bee colonies and over 62,000 beekeepers (Český rozhlas, 2020). Czech beekeepers produce between seven and eight thousand tonnes of honey annually, with about a fifth of the honey going for export. However, Czech honey is also imported, mainly from Ukraine (the question to be asked is to what extent this situation remains the same in 2023), China, Uruguay and Germany (BussinesINFO, 2018).

The use of ICT in beekeeping

Increasingly, honeybee colonies are facing various challenges such as climate change, pesticides, and land use that affect their growth, reproduction, and sustainability (LeBuhn and Vargas Luna, 2021). The decline of honeybee colonies is a serious problem that leads not only to a reduction in honey production and quality, but also to a reduction in the pollination service that bees provide to ecosystems, and consequently to greater difficulties in maintaining native plants (Robustillo et al., 2022). Therefore, there are increasing efforts to help beekeepers also through ICT. In the first instance, the digitalization of beekeeping entails incorporating Internet of Things (IoT) technologies, e.g. sensors, to obtain and transmit data concerning bees. Subsequently, data analysis becomes vital as it enables the creation of models that create correlations between the collected data and the biological conditions of beehives, frequently employing artificial intelligence (AI) algorithms (Hadjur et al., 2022).

The interest in continuous monitoring of honey bee colonies, defined here as collecting data from the colony every hour or more frequently for more than two days, is not new (Meikle and Holst, 2015). Gates (1914) reported in 1907 hourly temperature data collected from the colony over several days. The use of ICT is also possible in beekeeping, where beekeeping solutions are increasingly offered. Smaller, cheaper and more accurate sensors, together with easier access to computers and the internet (Faludi, 2010), have enabled bee researchers and beekeepers to monitor many physical aspects of bee colonies around the clock, remotely and with little human labour (Meikle and Holst, 2015). Similarly, monitoring systems offer a reliable means of accessing, visualising, sharing, and managing data collected from agricultural and livestock activities, benefiting stakeholders in these respective fields. (Eitzinger et al., 2019, Popović et al., 2017).

The honey production cycle takes place in hives where it depends on many factors such as temperature, relative humidity, and wind (Catania et al., 2011), where it can benefit from advanced smart technology (Zgank, 2020). Real-time remote monitoring of bee colonies using ICT can help beekeepers detect abnormalities and identify colony conditions. This data can be made available to beekeepers in a real-time web-based system (Zacepins et al., 2020). The data obtained from bee monitoring, e.g., weight and temperature, can also be used for comprehensive colony monitoring over a longer period. Subsequently, a wide range of information can help to predict future bee behaviour. In summary, according to Robustillo et al. (2022) PB was created in response to the need for optimal management of beekeeping, using technology and statistical methods to help beekeepers understand what is happening inside hives without having to open them and thus disturbing the colonies.

Monitoring systems for remote bee detection and its benefits

A well-designed monitoring system comprising modern software architecture, such as microservices, is invaluable for managing honey bee activities and ensuring their overall health within beehives (Aydin and Aydin, 2022). Additionally, the beekeeping system incorporates a remote hive monitoring software, facilitating beekeepers to conveniently check on their hives from the convenience of their own homes (Ammar et al., 2019).

To help beekeepers and facilitate the process of implementing PB solutions, local start-ups and entrepreneurs have begun to develop products and tools for remote colony monitoring and management (Zacepins et al., 2021). PB utilises advanced technology in the form of smart hives fitted with sensors to monitor the health of bee colonies. These sensors detect various parameters that indicate the state of the colonies and transmit this information to the beekeeper through web-based networks that can be accessed via smartphones. This allows the beekeeper to focus their attention on the hives that require urgent inspection. The sensors are connected to a microprocessor, which is powered by a battery and connected to a network to remotely transmit the collected data to a server. Currently, the two main types of microprocessors used for this purpose are Arduino and Raspberry Pi. The data harvested is then sent to the cloud for storage, analysis, and alarm generation. Some systems even provide beekeepers with an application that organises the data by hive, allowing for easy monitoring and management.

Most commonly, in addition to weight, the temperature and humidity in the hive are also measured, with data captured hourly and displayed in a web-based application (Zacepins et al., 2021). Utilising sensors enables hive observation without provoking disturbance. Conducting frequent and invasive hive inspections to collect field data on colony growth and phenology for assessing treatment effects can induce defensive behaviour from bees, potential robbing by other colonies, and jeopardising the queen's well-being, in addition to disrupting the hive environment. In contrast, the use of small, autonomous sensors, especially when connected to wireless networks, can supply real-time information without causing any disturbances (Meikle and Holst, 2015).

Several solutions are available for remote monitoring of bee colonies. According to Wakjira et al. (2021), the adoption of PB is growing in Europe, but its implementation in Africa and Asia is occuring at a slower rate. In recent studies, there is a trend towards utilising more electronics with increased sampling frequency to measure a variety of hive parameters (Meikle and Holst, 2015). Commercial or handcrafted solutions primarily monitor weight and temperature (Meikle et al., 2017). Technology can help beekeepers better understand colony behaviour without having to look inside the hive (Zacepins et al., 2021). According to Pejić et al. (2022), in the traditional approach, hives are typically inspected roughly 15 times per year. However, this method lacks the ability to provide beekeepers with real-time information about the condition of their colonies, preventing them from taking timely action. Remote monitoring of colonies minimises the number of visual inspections required; therefore, it helps reduce colony stress (Stalidzans et al., 2017). The use of PB allows beekeepers to monitor colonies for many possible reasons, such as research, information on the daily management of bees by beekeepers, and learning how to reduce resources and time allocated to tasks without reducing production (Gil-Lebrero et al., 2017). The beekeeping system monitors the beehive by exploiting images of in and out activities of bees in combination with measurable parameters, such as temperature, humidity, light, noise, beehive weight, and weather conditions (Ammar et al., 2019). Advanced ICT and remote sensing technologies enhance PB and assist in the increase of the role of bees in pollination services as well as the production of hive products while maintaining a healthy environment (Wakjira et al., 2021).

For the feeding activity of the colonies, the best solution is to use hive scales for continuous weight monitoring, where monitoring the weight of bees can help determine the start of an intense nectar flow and signal the beekeeper when additional stores need to be placed in the hive (Zacepins et al., 2021).

In recent years, several studies have underlined the potential of integrating digital technologies to monitor honey bees. A great deal of research has been carried out on IoT-based beekeeping monitoring systems (Aydin and Aydin, 2022). Meikle and Holst (2015) describe an overview of the parameters examined and methods used, including location, number of replicate colonies and duration of hourly datasets. When in the early days, weight and temperature were investigated using mechanical balance (Gates, 2014). In recent years, e.g., temperature (Stalidzans and Berzonis, 2013), vibration (Bencsik et al., 2011), acoustics, temperature, relative humidity (Ferrari et al., 2008) were measured using in-hive sensors. Forager traffic was measured using hive entrance sensors e.g., by Mezquida and Martínez (2009) and through RFID tags and entrance sensors (Schneider et al., 2012). Furthermore, relevant studies and its comparison according to nine different criteria were presented in the paper of Aydin and Ayding (2022), where monitoring system were categorized as WSN-based Audio Events Monitoring, WSN-based Beehive Monitoring; IoT-Gateway Design for Beehive Monitoring, Cloud-based Data Storage Architecture for Monitoring Bee's Behaviors, IoT-based Intelligent Beehive and Intelligent Factory; IoT-based Bee Colony Monitoring, AI-based Assistance System; IoT-based Bee Colony Monitoring and Bee Colony Real-Time Monitoring. Monitored metrics in the above-mentioned paper of Aydin and Aydin (2022) were temperature, humidity, sound, relative humidity, acceleration, rainfall, dust, light intensity, air contaminants, image, iight, smoke gas, weight, video, various gases concentration, entrance counts, pressure, altitude, carbon monoxide, nitrogen dioxide, hydrogen concentration, alcohol concentration, propane concentration, oxygen, carbon dioxide, ultraviolet, infrared light, liquefied petroleum gas and acoustic parameters.

Meikle and Holst (2015) report that the behaviour and condition of bee colonies can be monitored using temperature, humidity, acoustic, video, weight, and other sensors. There have been many studies on monitoring of colony parameters, and it is concluded that weight and temperature are the main ones because the cost compared to the information on the results is sufficient (Zacepins et al., 2020). Monitoring of colony weight provides one of the most important types of data a beekeeper can have on the colonies (Fitzgerald et al., 2015). Automated weight tracking systems can provide the beekeeper with important information about several important colony events (Meikle et al., 2008). The second important parameter of the colony is temperature, because bees can regulate the temperature inside the hive (Southwick, 1992). Measuring the temperature of honeybee colonies has the longest history and currently measuring the temperature of honeybee colonies appears to be the simplest and cheapest way to monitor honeybee colonies (Zacepins and Karasha, 2013). In fact, a temperature sensor is usually added to virtually every honeybee colony monitoring device (Zacepins et al., 2020). Long-term monitoring of bee colonies can lead to long-term data for better analysis and understanding of colony behaviour (Kviesis et al., 2020). As was mentioned above, Alerri et al. (2023) found that from 201 selected papers in Scopus database was 98 focused on internal temperature, 69 for relative humidity, 66 for mass in the sense of weight of the hive, 68 for sound, 27 concerning flight activity, specifically entry and exit of the hive (bee inflow/outflow). For the external parameters, 14 for wind speed and 12 for rainfall.

Incorporating sensors into the hives and processing the data, provides the beekeeper with real-time information on the status of the hives without having to travel to them, making decision-making easier and minimising resource consumption and stress in the hive (Robustillo et al., 2022). As the cost of end systems decreases and their precision and valuable outcomes increase, continuous and real-time monitoring of colony parameters is becoming more feasible even for smaller beekeepers. The implementation of PB systems is estimated to bring economic benefits to beekeepers (Zacepins et al., 2020). Another benefit includes a reduction in the number of manual spot checks, thereby reducing the impact of disturbance to bees (Zacepins et al., 2020). Frequent physical inspections of colonies disrupt the normal life of bees and can cause additional stress that negatively affects the productivity of the entire colony (Komasilovs et al., 2019). Similarly, scattered colony locations are often encountered and therefore suggest the need to facilitate 24/7 monitoring of animals, which can be facilitated by advanced smart environment technologies (Zgank, 2019).

Based on the research made by Zacepins et al. (2021) by 234 Latvian beekeepers showed that the most important areas for the beekeepers are: “Preserving bee colonies and ensuring the well-being of bees” (48% respondents), “Honey harvest” (41% respondents) and “Reduction of inspections” (36% respondents), which also dominates in all groups of beekeepers. Two less important areas for beekeepers in terms of use of digital tools are “Traceability of honey products” (44% respondents) and “Anti-theft and avoiding animal attacks” (57% respondents), which are not so evenly distributed among all groups of beekeepers and are slightly more preferred by professional beekeepers (Zacepins et al., 2021). For Latvian beekeepers is important to prevent theft and wildlife attacks from remotely located colonies, so video monitoring of colonies and GPS systems of colonies are important (Zacepins et al., 2021). Researchers in recent times began exploring the (IoT) potential as it relates to beekeeping (Tashakkori et al., 2021) and using AI. These fields are not covered in this paper.

Considering the growing interest of the researchers towards smart technologies in beekeeping, the research focused on this area was to map the interest in products for remote monitoring systems for bee detection in Czechia. The research does not look at the provision of ICT in beekeeping from a technical perspective, but from the perspective of users (beekeepers) and providers of these technologies. As confirmed by Zacepins et al. (2021) current beekeepers are more educated and technologically advanced and start to use and apply ICT solutions and tools more actively (Zacepins et al., 2023). To fulfil this aim, three research questions RQ1-RQ3 have been prepared:

RQ1: Who are the customers of PRM?

RQ2: What are the advantages of the PRM?

RQ3: What areas are slowing down implementation of PRM?

To answer these research questions, qualitative research was conducted with beekeepers, manufacturers/vendors of ICT in beekeeping and other beekeeping experts and entities within the country, so that the issue was processed from complex perspectives. This comprehensive view on the use of monitoring systems for remote bee detection in beekeeping is a clear contribution of this paper.

Materials and methods

The field of PB in the context of beekeepers and others within the apiculture sphere is not sufficiently explored. Therefore, the research was prepared to get new insights. Through interviews a comprehensive view of the issue is developed. Respondents were beekeepers, producers/sellers of product for remote monitoring (PRM) and other professionals and institutions related to beekeeping, see Figure 1. Beekeepers were divided into two groups, namely small beekeepers (called hobby beekeepers) with up to 60 colonies and large beekeepers (usually beekeeping is their main source of livelihood) with more than 60 colonies. This is the first qualitative research on this area in Czechia.

Figure 1 and Figure 2 show all respondents from all researched fields. Figure 1 shows three main groups of respondents, such as beekeepers, non-beekeepers and other apiculture entities. Figure 2 shows the respondents from the group of bee institutions. The number in the brackets shows the number of interviews. The total number of interviews was 67. All participants in the research were deeply connected with beekeeping and are professionals in this field.

To propose a broader understanding concerning the usage of PRM in Czechia, the research was conducted among many groups of respondents (see Figure 1 a Figure 2).

Some family members and many of the author's friends are beekeepers, so respondents for qualitative research were selected firstly on the basis of the knowledge and web search of the author of this paper. Secondly, snowball sampling (Coleman, 1958) was used, when the process began with suggestions from some possible respondents, who have some experience with PRM or are involved in beekeeping. Interviews lasted 20-90 minutes and were held from September 2022 to November 2023. The interviews were done personally or via online calls through Google Meet. One interview with a producer was done by company chat, where the questions were directly answered. The total number of interviews is 67 including 42 with beekeepers, 11 with bee institutions, 14 with no-beekeepers and companies cooperating with beekeepers.

The qualitative research undertaken via interviews consisted mostly of open-ended questions, which were partially based on the literature review, mostly

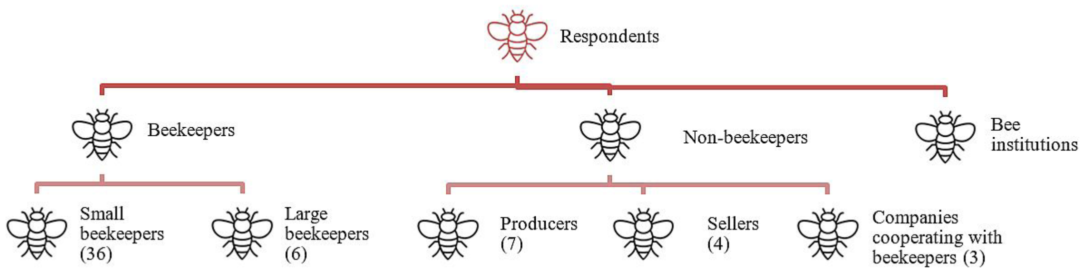

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Figure 1: Overview of three main groups of respondents.

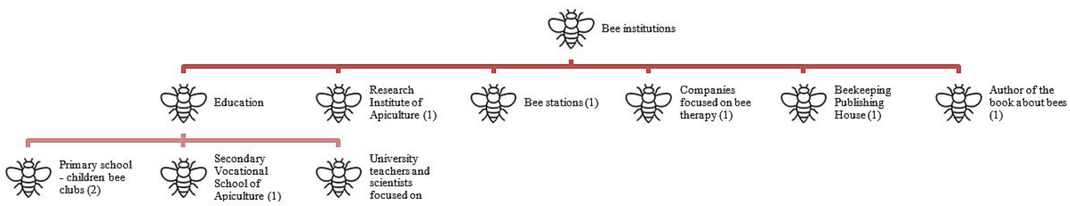

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Figure 2: Respondents from apiculture entities.

Zacipens et al. (2021). The rest of the questions were prepared in order to fulfil the aim of the research. The areas of research that are presented in this paper included the following aspects: Current situation in beekeeping with the focus on PRM; Main customers of PRM; Advantage of PRM; and Areas of slowing down implementation of PRM. The questions were almost identical for all respondents involved. The aim of the comprehensive and complex research was to learn about PRM issues from multiple perspectives.

The interviews were mostly recorded and transcribed. Open coding was used to organise the data from open-ended questions and convert them into discrete thematic blocks. Based on the initial research focused on RQ2, a total of 28 first-order categories for advantages of PRM were identified. These categories were further analysed to identify similarities and differences. During this process, the number of codes was reduced, resulting in the identification of four aggregate themes: Information, Control, Activity/ Reaction and Savings. The final coding structure, showcasing these themes, is presented in Table 1. Similarly, from the research focused on RQ3, a total of 42 first-order categories for area slow down implementation of PRM were identified. These categories were further analysed to identify similarities and differences. During this process, the number of codes was reduced, resulting in the identification of six aggregate themes: Unawareness, Disinterest, Tradition, Beekeeper, PRM operation and Price of PRM. Even after some consultations with bee professionals, there is still a degree of subjectivity in the categorisation. Direct interview quotations were added to increase the transparency and credibility of the findings.

As qualitative case research is sensitive to researchers' subjective explanations, some peer consultation was needed to avoid researcher bias and to ensure greater objectivity in the study. A rich set of direct interview quotations to demonstrate interpretations was added to support the transparency and conformability of the findings.

Results and discussion

Specifics of the Czech market in relation to PRM in beekeeping

Bee monitoring is not something new. Bees have been monitored in the Czech environment for a long-time using devices that were usually made by amateurs and technically proficient beekeepers. Most often, the weight of the hive or the temperature was monitored, even with a simple thermometer. Professional devices were often born in the minds of beekeepers who lacked these more advanced devices in their beekeeping.

The current situation in the Czech environment is such that many manufacturers and sellers unfortunately perceive certain shortcomings in the sale of remote monitoring of beehive weight. For most beekeepers, a better-quality solution is too expensive and not worthwhile. One PRM measures the activity of only one hive, and usually beekeepers have multiple hives, so this also increases the cost of acquisition. With cheaper solutions there is some risk in the quality of the equipment, the monitoring itself and the data transmission. There are smaller garage companies on the market where their products have different designs, features, variable quality and are not very reliable. Also, the data display and the way the platform would need to be improved, often they just send a file or put something on the web.

Beekeeping is still associated with a certain conservatism, traditional beekeeping methods, older age of beekeepers, rural areas and the penetration of modern technology is slower among beekeepers. Of course, all this is gradually changing and improving. However, the younger generation is becoming more involved in beekeeping, their relationship with modern technology is much better and constant monitoring of data (bees) is much more natural for them. Also, it is these devices that can help young and novice beekeepers to navigate the bee care environment better and more quickly.

To sum up, more interest in these products, such as PRM, can be expected in the future, when overall IT literacy will increase, the benefits of these devices will be actively used by beekeepers and promotion about the benefits of these products will expand.

Interviews focused on mapping the interest of the use of PRM in beekeeping showed many interesting findings related to RQ1-RQ3. The findings to RQ1 – RQ3 are presented below along with a set of direct interview quotations, which support the transparency and conformability of the findings. Qualitative research is sensitive to researchers' subjective explanations, so some consultations with bee professionals were needed to eliminate researcher bias.

RQ1: Who are the customers of PRM?

The findings from the interviews showed that the interest of manufacturers and sellers to offer these smart devices is significant, but the interest of beekeepers is rather less, due to the purchase price, weaker IT knowledge, traditional beekeeping practices, higher age of beekeepers and the joy of being personally with bees. All areas slowing down the implementation of PRM are mentioned below, see findings for RQ3.

Interviews with all stakeholders revealed that the typical PRM customer is a beekeeper who is between 30 and 50 years old and has a positive attitude towards PC/mobile and ICT (see Figure 3). Of course, there are also customers of PRM at older ages, even in their 80s, but they tended to be in the minority. Customers, or users, of PRM included, for example, beekeeping institutions, beekeeping institutes and companies on whose land the bees are located were also included in the research (see Figure 1 and Figure 2).

Also, Figure 3 shows the groups of beekeepers who use PRM, such as beekeepers who are beginners, young or experienced. Each group may see slightly different benefits of PRM, see RQ2, but the primary objective is the same - to be able to monitor the activities of their colony remotely.

Opinions on the "typical" beekeeper with a PRM were not entirely clear, but from the information from the interviews a more detailed characterization was prepared and is presented in Figure 3 and mainly in Figure 4.

As seen in Figure 4 the characteristics of beekeepers with PRM are varied and of course do not apply to all beekeepers. However, usually a large part of the characteristics is typical for customers/users. The characteristics could be further categorised into those related to the beekeeper themselves, such as lower fineness on tradition, (characteristics are marked in Figure 4 in italics), and those related to external environmental factors, such as higher income.

Some respondents' quotes focused on the characteristics of the customers are mentioned below:

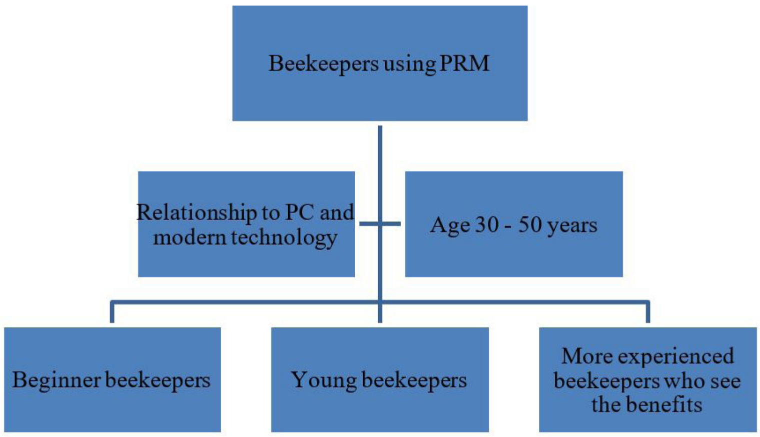

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Figure 3: Main characteristics of beekeepers with PRM.

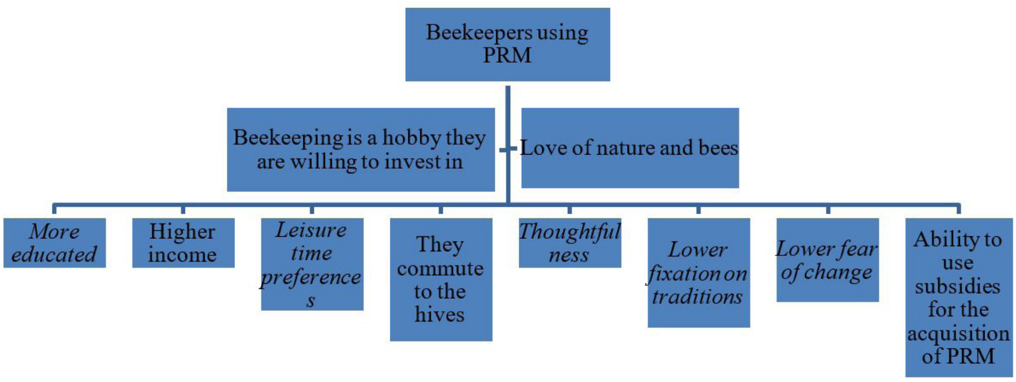

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Figure 4: Other characteristics of beekeepers with PRM.

"We have two main customer segments. The first is beekeepers aged 40-50 with a financial background, who usually do not use subsidies (they do not want to fill in forms), where PRM has the advantage of access to hive control information, where it is not necessary to be physically at the bees so often. The second segment is seniors who have bees at their cottage, which is far away, so they can monitor the bees remotely. They also work with beekeeping clubs, where the PRM kids really like it and are open to it, but the buyer is then the parent…" (Manufacturer 1)

"Our customers are mostly beekeepers who have bees located farther away and they are from so-called 4 groups: a) Toy beekeepers - want to know more about bees, b) don't have time, c) too careful - don't want to have any losses - swarming, theft, tree fall, and d) non-beekeepers -rent equipment or their bees to schools (they give schools the outputs from sensors and cameras, which is beneficial for teaching, e.g., work with graphs - use in mathematics, physics)." (Manufacturer 2)

"The younger generation who are more open to PC/technology, they have little time, so it's useful to them." (Teacher from children bee club).

"They definitely have to have a relationship with modern technology, and then they are also customers who get subsidies to buy PMR, so they try to buy, and some people move on, some people don't." (Manufacturer 3)

"For the young beekeepers, where PMR helps for better orientation and to absorb information, because they don't know much about bees yet and they want to help themselves a little bit with this, which helps them to accelerate their know-how on how to take care of bees." (Seller 1)

"This cannot be answered unequivocally. We have customers who are young, but also long-time beekeepers who are over 80 years old." (Manufacturer 4)

"Young and old, it's not about age, and it's not mass, but there is still interest... how to characterise them? They are definitely thoughtful people who are not fixed in traditions and are not afraid of change." (Manufacturer 5)

The results are probably not surprising, as it was expected that since PRM is linked to ICT, it would be closer to younger beekeepers who have no problems with ICT and moreover ICT is part of their work and personal life. Since many beekeepers are of a higher age, it could be expected that ICTs would be more distant for them and that they would also emphasise beekeeping according to their traditions and practices. It can be expected that in the coming years, as younger beekeepers become more and more aware of ICT, interest in PRM and other PB tools will also increase. Therefore, many PRM manufacturers/sellers are actively targeting younger and novice beekeepers. As Zacepins et al. (2023) state there is an enormous potential for an increase in Latvia, such as to shift the traditional method of apiary record making to the digital environment.

RQ2: What are the advantages of the PRM?

Based on the qualitative research, the respondents perceive the main advantage of PRM to be: Information, Control, Activity/Reaction and Savings. The final coding structure is shown in Table 1.

First-order categories		Aggregate themes
Hive weight information	→	Information
Hive temperature information	→	
Information about the swarm, swarm mood, motherlessness, mortality, etc.	→	
Information on stock levels, winter consumption, starvation	→	
Information about the beginning of bee brood and its end (healing)	→	
Information when the colony has a problem	→	
Instant overview of the whole bee.	→	
Change of hive location (wind, theft)	→	
Departure of bees (swarming)	→	
Tracking backwards even after years	→	
Information clearly in graphs	→	
Track the relationship between flowering/ weather and swarming	→	
Information without opening hives	→	
Better understanding of the colony	→	
Check the status of the colonies	→	Control
Check weights	→	
Temperature control	→	
Stock level check	→	
Observing and learning how the colony works	→	
Being able to react quickly as a beekeeper	→	Activity/ Reaction
Reducing the number of unnecessary checks	→	
Readiness for visiting bees	→	
Optimising work	→	
Helping with feeding	→	
Assistance with treatment	→	
Saving time on commuting	→	Savings
Saving commuting costs (e.g., petrol)	→	
Economic effect	→	

Source: Author

Table 1: Advantages of PRM.

Some respondents' quotes focused on the advantages are mentioned below:

"I go to the beehive and I'm ready - the day before I go to the computer and check what's going on and then it goes ready (like a car - use the dipstick to see how much gas, ...)." (Beekeeper 1)

"It's useful and I wonder who doesn't have it." (Manufacturer 1)

"Beekeeping is expensive, so the weight is lost then...it's a long shot." (Beekeeper 2)

"The battery lasts for 10 years, it's only replaceable, otherwise no work." (Beekeeper 3)

"It is definitely a benefit if the beekeeper wants to follow it." (Research Institute of Apiculture)

"Primary is weight, it is the most important and shows a lot of information, then temperature and humidity." (Beekeeper 4)

"I only use it on one hive. And more just out of interest, curiosity, and deepening experience. The biggest benefit is monitoring the weight." (Beekeeper 5)

"It is easy to find out the return from PMR, e.g., by the price of petrol and the number of visits to the bees required." (Manufacturer 1)

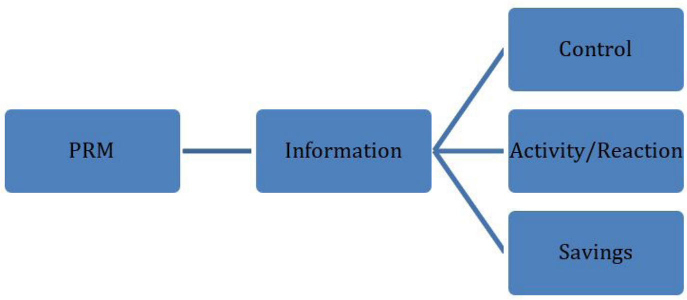
As shown in Table 1, the aggregate themes Information and Control are given separately, but they are certainly very closely related, rather the two areas are also intertwined. Similarly, the other themes are also very interlinked. Using the information that the beekeeper gets from the PMR, they can then control and react to what is happening in their colony. These Reactions/Actions to what is going on in the hive can then have the impact of saving time and saving cost in transport and dealing with the problem. Thus, it can be said that the benefits from PMR are overall comprehensive and build on each other as shown in Figure 5.

The benefits mapped in the Czech environment are consistent with the findings of Zacepins et al. (2021) for Latvian beekeepers, which are reported in theory, such as preserving bee colonies and ensuring the well-being of bees, reduction of inspections or antitheft. As was mentioned by Meikle and Holst (2015) the use of autonomous sensors enables observation of hives in real time without disturbance of bees.

The interviews revealed that the primary concern for beekeepers is to obtain information about hive activity. The most monitored parameters include weight and temperature monitoring, which correspond with Zacepins et al. (2020), where it is concluded based on many studies on monitoring of colony parameters that weight, and temperature are the main parameters because the cost compared to the information on the results is sufficient. It exactly shows the Savings benefit (see Table 1) that is associated with monitoring hive activity.

RQ3: What areas are slowing down implementation of PRM?

Based on the qualitative research, the respondents' areas which slow down implementation of PRM, are as follows: Unawareness, Disinterest, Tradition, Beekeeper, PRM operation and Price of PRM. The final coding structure is shown in Table 2.



Source: Author

Figure 5: Linking the advantages of PRM.

First-order categories		Aggregate themes
Unawareness of PMR	→	Ignorance
Little awareness of the benefits of PMR	→	
Lack of technical knowledge	→	
Insufficient knowledge of modern technologies	→	
Poorer understanding of PMR outputs (e.g., graphs)	→	
Little interest in technology, including PMR	→	Disinterest
PMR is not needed	→	
No interest in innovation	→	
No interest in PMR data/outputs	→	
PMR is not a necessity for beekeepers	→	
Distance to the hive	→	
Humidity and temperature in conventional beekeeping without research are useless	→	
Use does not mean better results	→	
It does not bring joy	→	
Traditional approach to beekeeping	→	Tradition
Reluctance to make changes	→	
Monitoring is no substitute for physical inspections (e.g., during the laying season)	→	
Visiting hives is not guided by monitoring at all	→	
Technology does not belong in hobby beekeeping	→	
Mechanical recording of weight data	→	
Distrust of PMR (and of Interest)	→	
The power of nature	→	
Higher age of beekeepers	→	Beekeeper
Unawareness or lack of interest in PC/IT technologies	→	
Joy of being with bees	→	
Reluctance to learn something new	→	
Reluctance to change their established practices	→	
Working with bees for a long time (great experience)	→	
Need to calibrate over a period of time	→	PRM operation
Poor mobile signal at the site	→	
Use of el. energy - disruption of bee biofield	→	
PMR unreliability (especially hive scales)	→	
Low PMR efficiency	→	
PMR complexity	→	
Complexity of PMR installation	→	
Ignorance of working with PMR	→	
1 hive = 1 hive scale	→	
Fear of PMR theft	→	
Higher purchase price of PMR	→	Price of PRM
Purchasing a PMR is an additional cost	→	
Priority to purchase other necessary equipment	→	
Reluctance or inexperience to apply for subsidies	→	

Source: Author

Table 2. Areas slowing down implementation of PRM.

For some information from respondents, as with Table 1, it was not entirely clear where to place them, such as distance to the hive. Certain areas of ambiguity were discussed with experts, but even so it was not always clear. Therefore, some respondents' quotes were added.

"Technology doesn't belong to hobby beekeeping because beekeeping is about observing bees, nature, about joy, about feelings. Being with bees is relaxation." (Beekeeper 1)

"Nature is wise, it can cope without our interference and waves." (Beekeeper 2)

"Now the priority was to get other necessary equipment, but we are going to take this step (buying a PMR) as well." (Beekeeper 3)

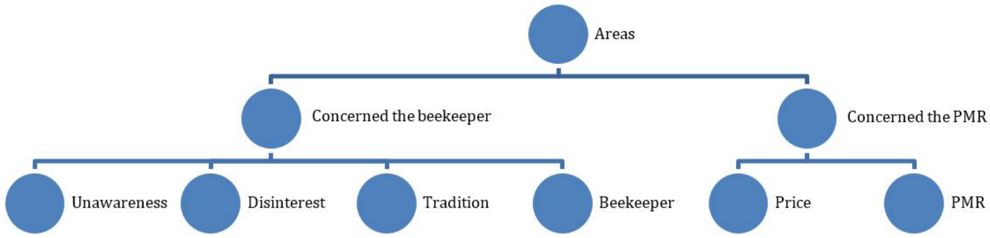
"I have bees in my garden near my house, so it (PRM) is not worth it." (Beekeeper 4)

"I have several locations with several hives, so it would not be worthwhile to get scales (PRMs) under all of them." (Beekeeper 5)

Based on the information from the interviews and their arrangement in Table 2, these six aggregate themes can then be divided into two areas. The first area concerned the beekeeper himself, where four aggregate themes (Unawareness, Disinterest, Tradition and Beekeeper) were given. The second area concerned the PRM where two themes (Price and PMR) were given. This division is shown in Figure 6.

As seen in Table 2 and Figure 6 the price of PRM is one area that reduces the expansion of PRM. Zacepins et al. (2020) mention that beekeepers are not usually keen on investing in digital solutions; therefore, the cost of smart hives becomes a crucial aspect, and should be reduced to the minimum possible (Zacepins et al., 2020), which could maybe help for faster expansion of PB. However, even though there are sufficient hardware and technical means for the practical application of PB, the market uptake of sensor-based decision support systems is still very low (Alleri et al., 2023). The main reason for this is the uncertainty about the economic benefits that the use of such systems could bring (Robustillo et al., 2022).

Another problem is that a PRM is only for one hive, and usually beekeepers have several hives in several locations. As Hadjur et al. (2022) state to decrease costs, only some of the hives per apiary could be equipped with sensors, supposing that different colonies in the same environment are in similar conditions.



Source: Author

Figure 6: The areas of slowing down implementation of the PRM.

Theoretical implications

Among the theoretical implications of the qualitative research, we can certainly mention the summarisation of the findings in the description of the specificities of PRM users (see Figure 3 and Figure 4), which are based on the research of both beekeepers, non-beekeepers and other apiculture entities (see Figure 1). Other implications include a sorting and categorization of interview outputs on two areas, namely a) advantages of PRM (Table 1) and b) areas slowing down the implementation of PRM (Table 2). The significance of these findings is certainly in the uniqueness of the topic under study, including the treatment of complex perspectives by many respondents from different groups, which increases the possibility of generalisation.

Managerial implications

Given the fact that most beekeepers are aware of modern practices, it would be good to focus on better education and promotion of PB, namely PRM. It would be beneficial to make beekeepers aware of the benefits of PRM through concrete examples and to show how the equipment works in real situations, what data it provides and what the data can be used for. It would also be good to emphasise awareness when installing the PRM, changing the battery and possibly other activities related to the PRM. As stated by Zapiens el al. (2021), to select a PRM, it is important to know a) the data transmission method and possible additional costs of data transmission (e.g., paying for the mobile network and SIM card), b) the size of the system to infer the possible location of the system (inside or outside the hive), and c) the battery life of the system (frequent battery replacement can lead to additional workload and frustration).

Practical demonstration and sharing of experiences with beekeepers who demonstrate PRMs seems to be key. Producers/vendors should prepare themselves for this form of education and aim for real contact with beekeepers at their beekeeping institutions, beekeeping events such as beekeeping seminars, fairs, balls, clubs, etc. Similarly, as Zacepins et al. (2021) mentioned to accelerate the uptake of precision beekeeping, more educational activities and information seminars for beekeepers are needed to explain the potential benefits that these technologies can bring. It would also be advisable to complement these offline activities with online activities, e.g., prepare educational videos, online seminars. Planned activities should be based on customer insights (see RQ1), and take findings from RQ2 and RQ3.

The results of the above research were presented by the author of the article to beekeepers and the professional beekeeping community at COLOSS: Olomouc Beekeeping Seminar 2023, in November 2023, where they were discussed.

Limitations of the paper

The following two areas can be considered as limitations of qualitative research. The first area is the lack of validation of the findings from the interviews with a larger sample of respondents. This could also be an opportunity for further research, where it would be interesting to find relationships between their approach to PB or PMR and the personality of the beekeeper. The second area of limitations relates to not including the use of AI in PB in the research. This area of further ICT development could also be considered in future research.

Conclusion

Today, it is almost impossible to imagine life without the use of ICT because they have also become part of modern agriculture, including beekeeping. In beekeeping, these technologies can be used for remote monitoring of bee colonies and for efficient colony management. Several solutions are available in the context of remote monitoring of bee colonies, mainly monitoring the weight and temperature of hives.

This paper contributes to the mapping of beekeepers' interest in the use of products with monitoring systems for remote bee detection in beekeeping in Czechia. Specifically, the paper focused on mapping the current state of the specifics of the Czech market in relation to PRM in beekeeping, description of PRM customers, benefits of PRM and areas of slowdown in PRM implementation.

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