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SWISSAID

FINAL REPORT

Citizen Science as an Ecological Research Tool: Mapping & Monitoring Bee Mortality in Ecuador

A collaborative pilot project by the Geneva Graduate Institute and SWISSAID Ecuador

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EXECUTIVE SUMMARY

1. **Background**: Increased bee mortality and occurrences of colony collapse disorder are observable in various regions worldwide. However, conservation efforts are hampered by a shortfall in knowledge about the trends and status of both wild and managed species. Given the continent's role in the global honey production and its dependency on pollinators, this is of particular concern for many South American countries, among them Ecuador. In Ecuador, the issue is very little documented and remains largely unquantified.

2. **Objectives**: This research project is embedded in a long-term study conducted by SWISSAID Ecuador and the Ecuadorian Collective in Defense of Pollinators, which aims to analyze and quantify the trajectories of local bee populations. The goal was to design, implement and validate a national monitoring and mapping scheme that is able to address existing knowledge gaps, enhance the understanding of the drivers behind bee decline and inform appropriate conservation strategies.

3. **Proposed Solution**: Leveraging the promising approach of citizen science and open-source digital technology, we developed a web-based monitoring tool that enables Ecuadorian beekeepers to record data on bee health and colony losses via mixed-method survey. The tool is user-friendly, community-based and free of charge. With the goal of sharing the collected information in real-time and building knowledge, we also developed an accessible visualization platform. It is designed to support the facilitation and interpretation of results.

4. **Limitations**: The quality and accuracy of the collected data may be inadequate due to bias, lack of participant's engagement, or inaccessibility of the monitoring scheme. In order to assess bee population trends year-to-year, the monitoring must also run over a long time period, which in turn requires considerable resources. Furthermore, any fundamental restructurings of the survey and/or other parts of the monitoring scheme could lead to incomplete or inconsistent data sets. More generally, the survey comprises only data about certain managed bee species (honey bees and native stingless bees), it is therefore not an appropriate tool for drawing conclusions about wild populations or insect pollinators overall.

5. **Recommendations**: To achieve measurements that meet quality thresholds, we recommend that beekeepers be sufficiently familiarized with the scheme, that those who are unable to use the tools themselves are not excluded but offered alternative means of participation, and that both their personal learning experiences and contributions to the scientific inquiry be acknowledged to foster networking, active knowledge-sharing and a sense of community. We also recommend translating the survey questions from standard Spanish into local dialects and indigenous languages in order to expand its reach and accessibility. Lastly, we recommend that the Collective in Defense of Pollinators implements sound data practices and a method to evaluate progress and success of the program.

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Finally, we would like to thank SWISSAID Ecuador for their project delegation and trust in partnering with the Geneva Graduate Institute.

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LIST OF ACRONYMS

Abbreviation	Definition
CCD	Colony Collapse Disorder
CDP	Colectivo en Defensa de los Polinizadores (Engl. *Collective in Defense of Pollinators*)
CS	Citizen Science
MAG	Ministerio de Agricultura y Ganadería (Engl. *Ministry of Agriculture and Livestock*)
SOLATINA	Sociedad Latinoamericana de Investigación en Abejas (Engl. *Latin American Society of Bee Research*)

1 INTRODUCTION

In recent years, it has been reported around the world that wild bees are declining and managed bee populations are increasingly lost (ECA, 2020). A first global assessment, published by the IPBES in 2016, confirmed this negative trend. It concluded that bees and other pollinating insect species are overall decreasing in abundance and diversity, driven mainly by human activities such as deforestation, agricultural intensification, use of pesticides and chemical fertilizers, and urbanization (IPBES, 2016). Among the most affected species are honey bees (Ibid). Their populations are endangered by invasive alien species, immunodeficiencies, and infections with pathogens, especially those transmitted by mites. Alone or in combination, these factors can lead to colony collapse disorder (CCD), a phenomenon that occurs when the majority of worker bees is lost, with the result of abnormally high colony mortality (James and Li, 2012).

To date, evidence about bee population declines has come primarily from studies examining aggregate changes in species richness (Wood et al., 2020). Large-scale monitoring and quantitative assessments of changes in population sizes require considerable effort and are therefore much rarer (ibid.). Consequently, although beekeepers around the world have reported increased colony losses and occurrences of CCD, the full picture is not known and data regarding bee mortality remains deficient. In fact, for over 55% of wild and managed bee species worldwide, population trends are either unknown or available for only a small part of their distribution (IPBES, 2016). Especially outside of Western Europe and North America, the lack of quantifiable data and information about bee health precludes any general statement on their regional status.

There is great need to address these knowledge gaps and investigate disparities in scientific production. Developing countries in particular are often highly dependent on agricultural production. Bees are therefore of paramount importance for the health of their ecosystems and economies. Beekeeping also provides an important source of income for many rural livelihoods: in 2021, an average of 1.8 million tonnes of honey were produced worldwide (FAO, 2021). Given their important role as part of the global honey supply chain, the lack of sufficient monitoring programs is of particular concern to many countries in South America, including Ecuador. Ecuador is considered a global biodiversity hotspot. It is also a major producer of commercial honey and heavily dependent on pollinators for food production. Despite knowledge of the (often interrelated) factors affecting bee health and mortality, robust data on bee populations is scarce. Because much of Ecuador's honey production is informal, there is little information on the actual production costs of beekeeping, and losses in bee populations – albeit observable – remain largely unquantified (Beltrán and Robalino, 2020; Martin-Culma et al., 2018).

The objective of this project was to help fill these data gaps by enabling a long-term national monitoring scheme on the population trajectory of managed bees and collecting empirical data on likely drivers of observed declines and CCD, so that conservation strategies to mitigate them may be implemented. Because of the huge quantity of work necessary to do so appropriately, we leveraged (1) the practice of citizen science (CS), which involves volunteers in the collection of data, and (2) open-source computational technologies, which are increasingly sophisticated and available at low cost. Our approach is based on the assumption that the current absence of bee monitoring programs in Ecuador is largely due to limited organizational and collaborational capacities. The program is therefore set up as community-based. It consists of (1) an online

monitoring tool and (2) a mapping application, both to be run and maintained by the Ecuadorian Colectivo en Defensa de los Polinizadores (CDP). Following the examples of other countries (see e.g. '*Abejas de miel Yucatán*' in Mexico, '*SOS Polinizadores*' in Chile or '*Polinizadores sin Fronteras*' in Nicaragua and Costa Rica (Calero-Pérez et al., 2022)), the project requires Ecuadorian beekeepers who keep either honey bees (apiculture) or native stingless bees (meliponiculture) to record losses among their managed bee populations through an online survey. Their answers are mapped and made accessible in real-time. Although limited by a variety of challenges and unknowns in the long term, such as sustained participant engagement and the impact of our methodology on volunteers' responses, we conclude that CS is able to increase the scale of ecological field studies while material costs are kept to a minimum. Complementary to more localized, hypothesis-driven research, this pilot project thus provides a viable scheme for obtaining the base-line data needed to assess population trends of managed bees and occurrences of CCD in Ecuador.

2 MATERIALS & METHOD

Our method is based on a three-steps approach. First, we conducted a literature review to establish the state of current research and resources available regarding beekeeping in Ecuador, existing bee monitoring programs worldwide and CS as a research practice in ecology. Second, we designed and built a pilot monitoring and mapping scheme that allows local beekeepers to report observed colony losses, thereby creating centralized and accessible baseline data at large spatial and temporal scale. Third, we validated our system with practitioners and feedback from Ecuadorian beekeepers in order to refine and improve it.

Throughout these steps, we worked closely with the CDP, an Ecuadorian multidisciplinary civil society organization founded in 2018. The CDP will manage and maintain the CS tools presented herein.

2.1 Project Primer: Reviewing Context and Best Practices

Our literature review sought to create an overview of the state of knowledge on topics linked to the project's objectives. The review thus focused primarily on the Ecuadorian beekeeping landscape and 'lessons learned' of established CS programs.

The Beekeeping Landscape in Ecuador

In 2018, the Ecuadorian Ministry of Agriculture and Livestock (MAG) ballot-counted 1'760 individuals carrying out beekeeping as an agricultural practice across the country, owning a total of close to 20'000 hives and providing national markets with bee honey, pollen, propolis and wax (MAG, 2018). The beekeepers keep honey bees (apiculture) and/or native stingless bees (meliponiculture). The vast majority of them are located in la Sierra, the Andean part of the country, or on the coast, with only a small number found in the Amazonian rainforest (MAG, 2016). Beekeepers in Ecuador generally tend to keep only a few (< 10) hives. Regional reports highlight that honey production chains are mostly artisanal. Entrepreneurial beekeeping with the aim of generating profit is rare (Vivanco et al., 2020).

Regarding colony losses of recent years, Ecuador has been taking part in the conduction of an international survey by the Sociedad Latinoamericana de Investigación en Abejas (SOLATINA). The association, which was created in 2016, developed a unified questionnaire of colony losses based on countries' BIP (Requier et al., 2018). The questionnaire was adapted to address aspects of Latin-American climatic conditions and includes alternative beekeeping activities such as meliponiculture. In 2017, it was distributed to beekeepers in 10 countries, Ecuador being one of them. However, while inter- and intra-country variability of colony losses may occur, there is still a critical lack of simultaneous and standardized estimates of colony losses that prevent any firm conclusions about the status of managed bees in Ecuador, unless substantiated by more large-scale and longer-term data.

Citizen Science: Potential and Challenges

An increasingly popular and tried way to generate such data is CS. Broadly speaking, CS describes the involvement of volunteers in the scientific process, i.e. data collection, analysis and interpretation of results. Although CS records are usually opportunistically gathered and result from “non-professionals'' (Kobori et al., 2016), they have been shown to deliver substantive insights, particularly in the fields of landscape ecology and macroecology (Brown and Williams, 2019; Poisson et al., 2020). By involving volunteers, CS projects are also manageable at low cost, allowing such initiatives to fill data gaps and produce data sets more frequently and at otherwise impossible geographic scales (Fraisl et al., 2022; Silvertown, 2009; Kosmala et al., 2016).

In the case of Ecuador, we evaluated whether it was possible and preferable to conduct a national CS program and found that the undertaking could achieve a variety of outcomes. First and foremost, it would be possible to generate baseline data at the necessary spatial and temporal scale. Since the data collection through volunteers requires little funding, it is more easily maintained over a long period of time. Such a program could also have societal impacts (e.g. heightened awareness about CCD and the agricultural importance of insect pollinators), policy impacts (e.g. more effective legislation to protect bees), personal and professional benefits for participants (e.g. a strengthened network and sense of community), and even positively influence environmental stewardship (Dickinson et al., 2012; Druschke and Seltzer, 2012; Fraisl et al., 2022).

Notwithstanding its potential, conducting CS also bears challenges and limitations that need to be considered. We identified a variety of potential barriers to a successful pilot program in Ecuador, including bias in the collection of data, uneven recording density, lack of necessary skills outside the research itself (e.g. community building and participant management), lack of participant engagement, underrepresentation of certain groups (e.g. people who live in remote or unsafe areas, areas with poor mobile network coverage or high illiteracy levels), deficits in data practices, and more generally the lack of field experience with CS projects in developing countries (see Fraisl et al., 2022; Requier et al., 2020; Bloom and Crowder, 2020).

Conceptual Project Design

In order to address these barriers in the development of our tools, we have (1) worked towards an overview of similar projects, available methods and resources, (2) assessed the spatial and temporal scale of the project as well as the type and amount of data needed to obtain the desired results, (3) defined the target groups of the project, (4) defined participant’s tasks in detail, and (5) evaluated individual safety and privacy issues related to the data collection.

> **Overview of similar projects, available methods and resources**: There is a wealth of running long-term CS bee monitoring programs worldwide. The main research subjects of these programs are distributional ecology, natural history, and plant-pollinator interactions. Only a handful of studies are addressing agricultural practices and toxicology (Koffler et al., 2021). In terms of methods, a lot of CS bee studies rely on data collected through sensors/hive monitoring or public observations and identification, but we have also found questionnaires that aim specifically at quantifying colony losses, e.g. by Bee Informed (USA), COLOSS (Northern Europe), and the EPILOBEE Program (France). In Ecuador, the unified survey from SOLATINA has been in use. Generally, there are many efforts to make CS tools and resources publicly available. For project planning, several online toolkits have been published, e.g. through SciStarter, the EU project ACTION, and WeObserve. For project creation and data collection, there are various web-based tools, e.g. CitSci, GeoKey and iNaturalist. After framing our use case, we decided to develop our project using the open-source applications EpiCollect5 and MicroReact.

Spatial and temporal scale of the required data: Our pilot is designed to cover all provinces of Ecuador, including the Galápagos Islands. In order to map the results obtained, GPS coordinates are linked to each data point. There is no pre-defined time period for the project: it is set up to allow for long-term, extensive data collection over many years from 2023 onwards, which will be necessary to generate robust information about trends in bee mortality and CCD. The data collected is mixed-method. The CDP assures sound data practices by periodically screening the results and checking for potential outliers.

Target groups: The main target participants of our pilot are Ecuadorian beekeepers, both in apiculture and meliponiculture, who are part of the CDP's database (n=200). By engaging specifically and exclusively beekeepers, it can be presumed that participants already possess a high level of knowledge about the subject at hand, which assures relatively high quality and accuracy of the gathered data. Their daily involvement with bees further enables the collection of data at a high frequency and lowers the risk of inactiveness or non-engagement. Most of the beekeepers in the CDP's database live in rural areas. A majority of them do not see themselves as professional beekeepers. They generally have access to a cell phone. Some may have difficulties with digital technologies, e.g. with filling out forms online. All of them speak (Ecuadorian/Andean) Spanish.

Participants' tasks: Beekeepers are asked to complete a web-based questionnaire upon encountering the loss of a colony, providing information on their bees' health, location of hives and possible causes. Volunteers from CDP may help with this task if needed via telephone calls or field visits, which, as an alternative method of recording participants' responses, lowers the risk of representation bias and exclusion of individuals with limited access to electricity, low levels of literacy or difficulties using digital technologies. The collected data is made publicly available to participants for community-building purposes and real-time knowledge sharing. Their contributions to the project are further acknowledged by providing them with an accessible visualization tool.

Individual safety and privacy issues: There are risks involved for participants upon sharing location data, as this may encourage theft of bees or expose them in some other way. These risks are disclosed to beekeepers prior to their participation with the option of linking less precise GPS data to their data entries. There are also privacy concerns to be considered. The pilot project is designed in compliance with Ecuadorian Personal Data Protection Law. No identifying data is collected. Data that is made public is sufficiently anonymized.

2.2 From Design to Implementation

In a second step, we built a CS pilot with the working title 'ECU Polinizadores'. ECU Polinizadores consists of two parts: a monitoring survey and a mapping application. For the first part, we selected questions commonly used in other monitoring programs, in particular the questionnaire of SOLATINA that has already been in use. We adapted the survey questions to account for data gaps specific to the Ecuadorian beekeeping landscape, including possible drivers of bee mortality and products obtained through beekeeping activities. We opted for EpiCollect5 as a platform to host our questionnaire, which is available both as a web page and mobile application. For the second part, we created an automatic integration that maps the results from the survey in an intuitively understandable and accessible way. The visualization is hosted on Microreact.

ECU Polinizadores: Logic Model

Situation: Lack of essential data/lack of tools to measure bee mortality and CCD in Ecuador.
Assumption: Generating long-term, robust data on bee health and CCD will incentivize the government to improve legislation, introduce bee-friendly policies and increase insect conservation efforts.

Inputs	Outputs		Outcomes		
Investments	Activities	Participation	Short-term: **Learning**	Medium-term: **Action**	Long-term: **Impact**
Technical and financial resources for (1) **Monitoring (Data Collection)** (2) **Mapping (Data Visualization)** Maintenance of infrastructure and tools	'World Bee Day' and other events	Mixed-method survey filled out by beekeepers who experienced colony death(s) Reach of 200 beekeepers across all Ecuadorian provinces	(1) **Data collection:** Long-term assessment of CCD and bee mortality in Ecuador (2) **Data Visualization:** Use for participants, policymakers and science practitioners	Promotion of community engagement, knowledge and capacities	Increased awareness and visibility Increased policy support

2.3 Validation

As a last step, we tested and validated the scheme we had developed. To that end, we used two main indicators: the quality of the first data entries (n=54) and feedback from participants (n=2). Our baseline data points for the primary validation of the system were previously recorded through the SOLATINA questionnaire. Since some of our questions for ECU Polinizadores were derived from the SOLATINA survey, we entered the data as a first validity and user experience test. CDP provided us with additional feedback from Ecuadorian beekeepers after presenting to their community the first version. Lastly, we conducted interviews with two Ecuadorian beekeepers who provided us with further insights on the accessibility and usability of our web-based survey and visualization platform.

Grounded Theory

Throughout the validation phase, we drew on grounded theory, an approach generating conceptual frameworks from data analysis rather than through testing pre-existing theories. A key feature of this approach is that data collection and analysis are done simultaneously so as to lead to further data collection based on foregoing findings. This iterative process enables the elaboration of emerging theory (see Glaser and Strauss, 2017). Simultaneously testing our system and asking for users' feedback allowed us to refine our method, and to continuously adapt it to the beekeepers' and the CDP's needs.

Research Ethics in a Participatory Setting

Our research draws on the lived experiences of communities and we had to ensure it was ethically sound. The guiding principles underpinning our research and data stewardship are informed consent, confidentiality and anonymity. Respondents volunteered to be interviewed, and the overall objective was always clearly communicated beforehand. We did not gather, record, or display any information other than what is presented in this report.

3 ANALYSIS

3.1 ‘ECU Polinizadores’

Monitoring: EpiCollect5

After assessing our use case, we built our pilot monitoring survey on EpiCollect5. EpiCollect5 is a free and easy-to-use data-gathering application. As a customizable back- and front-end user interface, it is available both on PC and mobile phones (downloadable for iOS and Android). EpiCollect5 is available in Spanish, involves an easy sign-up procedure, allows for unlimited data entries, and includes daily back-ups on British servers. Participants can enter data either through the project’s website (linked below) or via mobile app. The latter can be accessed offline, but requires access to the internet for the upload of data entries. Maintained by the University of Oxford’s Big Data Institute and funded by multiple foundations, it is unlikely that EpiCollect5 will be monetized or removed as a resource in the future. Another important characteristic of the tool is that it uses read-only API keys, meaning third parties can view, but not modify the data entries.

Project Link EpiCollect5:
ECU Polinizadores

Image: ECU Polinizadores project overview and mobile survey

Survey Questions

Following interviews with members from the CDP, we drafted and refined a total of 20 questions that participating beekeepers are asked to answer. After a brief project introduction and privacy policy disclaimer, participants are required to enter the date and their last name. If they have access to a device with GPS, the survey automatically records their location. GPS data can also be added manually. For safety reasons, the degree of accuracy of all location data is modified. The next questions regard the beekeepers' activities, asking for the type (apiculture, meliponiculture, or both), level of dedication (professional, semi-professional, or recreational), number of hives, type of bee species, and products obtained. In order to make the survey intuitive and easy to understand, most of the questions are closed-end and have pre-formulated answers to choose from. In the last part, beekeepers are asked to fill in quantitative data about the number of bee colonies they own and lost, as well as qualitative data regarding possible reasons, again with pre-formulated answer opportunities. At the very end, they may add a photo of the colonies that died (see Annex I for the full list of questions).

User Feedback

On International World Bee Day (May 20, 2023), the CDP organized an event on apiculture and meliponiculture in Chontapunta, Ecuador. They introduced our EpiCollect5 project to the local beekeeping community, tested the application and collected feedback from the beekeepers present. Subsequently, we made changes to the question format, added a safety disclaimer about the collection of GPS data, and slightly re-defined the use case of the tool. As part of the validation step, we interviewed two beekeepers about the overall functionality and content of the survey, about their user experience, and their understanding of the questions. Based on their suggestions, we added a photo option and refined the wording of some of the questions (see Annex II for interview transcripts).

Mapping: MicroReact

In order to visualize the data collected, we programmed an API integration that periodically exports data designated for public access (in a reduced and anonymized form) from EpiCollect5 to a platform called MicroReact. MicroReact, originally developed for the tracing and sharing of genomic epidemiology, is a free web platform that allows users to upload and map data linked to geographic locations. Any number of meta fields can be defined. People accessing the project web site can specify the colors and/or shapes to display the data. Since temporal data is included in ECU Polinizadores, a time slider allows the filtering of data based on time windows. We developed a default view that colors the data points by trend (see Annex I, Q20) and added a graph depicting colonies lost relative to total colonies owned.

Project Link MicroReact:
ECU Polinizadores

Same as with EpiCollect5, there is no limit to data entries on MicroReact and the platform is hosted as an open-source platform. Because of its high degree of customization and simple user interface, we recommend to CDP the use of MicroReact to visualize and facilitate the interpretation of results.

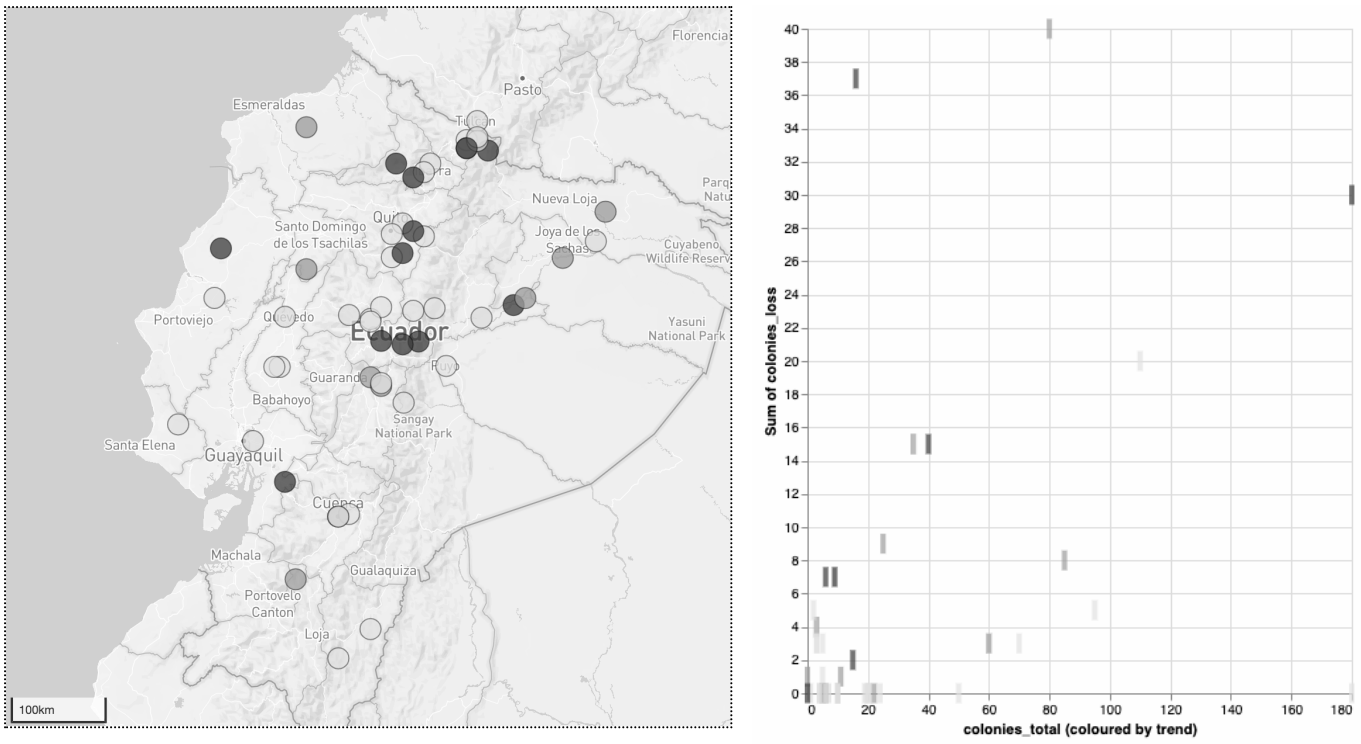

Image: ECU Polinizadores project default view with map and graph depicting relative colony loss

3.2 Technical and Regulatory Constraints

Because the 'ECU Polinizadores' monitoring scheme is based on a CS approach and uses computational technologies, it is subject to inherent technological and regulatory constraints. First, there are device and operating system limitations: EpiCollect5 requires a smartphone or laptop to run. Microreact is only available as a web-page, and requires sufficient processing power and screen size. There are also accessibility and performance constraints. The recording and download of data entries requires internet connectivity of a certain bandwidth, which may be an issue for participants who live in remote areas with poor coverage. Furthermore, Epicollect5 is currently a read-only API, meaning only GET requests are exposed and integretable to third party applications such as Microreact.

Regarding regulatory issues, it was essential to pay careful attention to data protection and privacy laws. Complying with data protection laws is a legal requirement. Failure to meet the requirements can result in substantial fines, which a project like this could ill afford. Moreover, the viability of CS hinges not only on the quality and relevance of the generated data, but equally as much on the process through which the results were obtained. In view of the increased attention to the data protection rights of citizens, we have followed the General Data Protection Regulation (GDPR) as well as Ecuadorian Personal Data Protection Law. The first notably sets forth a principle of 'data minimization', which is why identifying and sensitive data (e.g. full name and address) had to be excluded from the survey. Given that the data is publicly accessible, we ensured sufficient anonymization of all data entries, but certain risks cannot be accounted for, for example unauthorized access to the project's form-building structure, loss or theft of data pre-pseudonymization, or misdirected sharing of project links.

4 RESULTS

4.1 Preliminary Results and User Feedback

The current lack of tools to monitor and map bee population trends in Ecuador is likely due to the fact that developing and running such infrastructure requires financial resources and technical expertise that are not readily available. It has also been shown that logistical constraints such as lack of infrastructure and difficulties in recruiting volunteers hamper the establishing of CS initiatives. They are therefore far less commonly implemented in developing countries than in developed countries (Requier et al., 2020).

Preliminary Results

The objective of this project was to design, implement and validate a national monitoring and mapping scheme that is able to address existing knowledge gaps in Ecuador, enhance the understanding of the drivers behind bee decline and inform appropriate conservation strategies and policy efforts. As per July 7th, 2023, the scheme with the working title “ECU Polinizadores” counts 54 (n=54) baseline data entries. Out of the beekeepers who filled in the survey, 26% stated that they were non-professionals and 54% stated to be semi-professionals, which means that for the most part, bee products add financial revenues to their household incomes but are complementary to other professional activities. The remaining 20% of questioned beekeepers are professionals, meaning their income is dependent on their hives’ production and they generally own and manage larger numbers of bee colonies. Approximately half of the participants indicated that the prevalent type of bee genetics in their colonies is the honey bee species apis melífera alansoni (africanizada). Others are raising apis melífera ligustica (italiana) or apis melífera carnica (carniola). A small number of beekeepers own hybrid species or native stingless bees. From the answers collected, what was reported most often as a cause of colony loss were health issues (such as varroosis, nosemosis and larvae’s diseases) and contamination problems (exposure to chemicals and pesticides). In connection to the latter, phosphorus, herbicides and the insecticide carbofuran were mentioned, as they were brought out onto neighboring crops of beans or passion fruits. 11% of beekeepers stated that environmental or climate issues (drought, cold winter, excessive rainfall, frost or wildfire) led to their colonies’ death. 4% reported problems with the queen. Overall, 35% of the surveyed beekeepers estimated that their losses of managed bee populations in 2023 was significantly higher than in the previous year. 28% find their losses to be normal or similar to previous time periods. 37% experienced little to no colony losses in the time period of question.

Visualizing these data points on Microreact, we can see that the participating beekeepers are spread throughout the country and across diverse climatic conditions, covering the area at a national scale. Although it may be prematurely to attempt to identify any patterns, it seems that beekeepers in the provinces of Carchi, Imbabura, Pichincha and Tungurahua (north and center of Ecuador) are suffering more from colony losses than in Southern provinces, where beekeepers reported relatively low mortality rates of their bees.

User Feedback

Because we used an iterative approach and worked closely with the CDP in identifying and refining the use case of the monitoring scheme, interviews have played a role throughout all phases of the project. However, it is particularly the interviews conducted with beekeepers (n=2) at the very end of the validation stage that are worth noting. Both beekeepers emphasized the topical relevance and value of a CS initiative. For the first time, one beekeeper said, it was possible "to identify where [beekeepers] are",[1] thus creating an opportunity to network and foster a sense of community. Beyond the common goal of creating scientifically robust knowledge, it was also stated that "it is relevant to know the data because one can, in a way, visualize the issue of colony loss and perhaps make it possible to denounce these deaths [...]".[2] 'Denunciar' in this context refers to bringing colony loss and CCD to the political agenda, for example by advocating for greater regulation of pesticide use and a ban on the most toxic insecticides.

On some of our questions, we received diverging opinions. For example, while one beekeeper indicated a preference to use scientific species names when asked about dominant genetics in the survey, the other did not have a preference. And while one beekeeper explicitly welcomed the GPS feature of the Epicollect5 questionnaire, concerns were also raised about hive theft or otherwise being at risk of being compromised. It was also pointed out that some beekeepers may want to fill out the survey while being away from their hives, thus potentially reporting colony losses with erroneous localisation data.

4.2 Project Benefits and Risks

Benefits

EpiCollect5's various features will benefit both beekeepers and the CDP in many ways. Its ease of use, hosting stability and versatility allows the CDP to gather and store large amounts of information at no cost and over long time periods. Other functionalities, such as filtering data entries by title, assigning different user profiles with leveled access rights and export options guarantee for an overall high manageability of 'ECU Polinizadores'.

Meanwhile, the web application on Microreact is a useful, if not necessary, addition to the monitoring scheme as it aids the interpretation of the collected data sets. It is a flexible and interactive software: its output and associated data are presented in an accessible way for a wide range of end users. The visualization can be shared as a permanent web link among collaborators, or embedded within publications to enable readers to explore and download the data. By acting as an endpoint for the monitoring tool, Microreact provides a simple, yet powerful, visualization method that can greatly aid the facilitation of results and the open sharing of the raw data collected on EpiCollect5.

Overall, we find that 'ECU Polinizadores' is a viable option to generate the data necessary for quantifying the trajectories of local bee populations in Ecuador. It certainly has the potential to be a successful CS project in the long term, given that its limitations and risks are duly considered.

[1] In Spanish (orig.) : "Para el Colectivo, también es muy útil. Para poder identificar dónde estamos."

[2] In Spanish (orig.): "Si es relevante conocer los datos porque uno puede con esto de una manera visualizar el tema de la pérdida de colmenas y tal vez es que si el va como antecedente para hacer posible es denunciar, de sus muerte, de los abandonamientos."

Internal Project Limitations

First, it needs to be highlighted that the survey questions have only been preliminarily validated. It will likely be necessary to further refine the wording or structure of the questionnaire, which in some cases might lead to incomplete or incoherent sets of data. Practicality, relevance of the generated data and user-friendliness also remain to be confirmed by a larger number of respondents. We conducted very few interviews, and although crucial in the adaptation of the question's framework and format, it will be advisable to present participants with a feedback option for further comments and suggestions.

More critically, the accuracy of collected entries might fall short of data quality thresholds. This could be the case if the wording of certain questions is imprecise, if participants are unable to familiarize themselves with the interface and are therefore not keen to use it, or if there is no support or alternative method of data entry made available to them. It is also possible that participant's engagement is not long-lasting, or that funding issues or organizational limitations within the CDP bring the data collection to a stop before bee populations trends can be adequately assessed.

To date, EpiCollect5 is available only in standard Spanish. However, there are at least 24 other dialects in Ecuador, such as Northern Quechua and other pre-colonial languages. It might be necessary to translate and adapt the survey questions and visualization application, should users report issues with comprehension.

Finally, it is important to note that 'ECU Polinizadores' was designed to generate baseline data about managed bee populations. Although adaptable to a certain extent, it might not be an appropriate tool to evaluate the status of wild bee populations or insect pollinators as a whole.

External Risks and Risk Management

External factors might impact the project as well. We identified misuse of the tool, sudden increases in costs and political upheavals as potential risks to the project's success, particularly because of the scheme's extended running time and the CDP's public exposure. Ensuring the safety and anonymity of beekeepers involved in the project is of high importance and should be given priority. While data on EpiCollect5 and Microreact is hosted on multiple servers in the United Kingdom, it might be advisable to periodically screen and download the generated data onto another third party application, in case either platform is monetized or no longer maintained.

5 MOVING FORWARD

Drawing on the foregoing the analysis and discussion of results, we would like to make the following recommendations for the usage of ‘ECU Polinizadores’ and its embedment in a larger research framework regarding bee mortality monitoring in Ecuador.

First, we recommend that participating beekeepers are adequately familiarized with EpiCollect5, for example by means of video instructions, in-person assistance or handouts. This will ensure comprehension and correct interpretation of the questions asked, as well as consistency and completeness of the generated data. We also recommend offering beekeepers an alternative method of data entry, for example through phone calls. Different methodologies may have an impact on participants' responses, but it would guarantee for more accessibility, bigger reach and granularity of answers, and include perspectives that may be critical for identifying national patterns and trends. Furthermore, we recommend that the survey and visualization platform be translated into local dialects and indigenous languages. This will allow for a more diverse group of participants, and generate potentially very valuable insights into indigenous and local practices.

Another key element will be to make sure that the contributions of beekeepers are continuously acknowledged and encouraged, and that participants garner personal benefits from it, for example networking opportunities, active knowledge-sharing and a fostered sense of community. One suggestion would be the creation of a linked communication channel, which allows beekeepers to anonymously chat online, share information and have a direct link to both the CDP and the Ecuadorian beekeeping community.

Finally, we recommend that the CDP implements sound data practices in order to navigate potential compliance and privacy issues. It will also be useful to establish a method and indicators to measure progress and evaluate the success of the project, and ensure it continues over the necessary period of time. Overall, the CDP will play a most crucial role in the further development and usage of the ‘ECU Polinizadores’ monitoring scheme.

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ANNEX

Annex I: Survey Form

‘ECU Polinizadores’ Survey on EpiCollect5

Disclaimer:

Esta aplicación fue diseñada para recopilar datos esenciales sobre pérdida de colmenas de abejas apis melíferas y abejas nativas sin aguijón en el Ecuador. Por favor, rellenar los campos de respuesta requeridos. Los datos son para consulta pública y uso abierto. Al proceder, usted acepta y espera que los datos generados por este proyecto estén disponibles en repositorios de datos digitales y que terceros puedan acceder a ellos. No le pediremos ningún dato sensible que pueda vincularse a su identidad.

1 Fecha: DATE Entry

2 Apellido: TEXT Entry

3 Ubicación (si usted NO desea revelar la ubicación de las colmenas, puede introducir las coordenadas de un punto cercano en un radio de 5 kilómetros): LONG/LAT Entry (automatic or manual)

4 Ciudad/comunidad más cercana: TEXT Entry

5 Tipo de actividad:

- ☐ Apicultura
- ☐ Meliponicultura
- ☐ Ambos

6 Dedicación:

- ☐ Profesional (es mi única fuente de ingreso)
- ☐ Semi profesional (es importante para mis ingresos familiares, pero poseo otra actividad/profesión complementaria)
- ☐ Soy criador para consumo familiar o personal

7 Número de apiarios y/o meliponarios: NUMBER Entry

8 Tipo de abeja: MULTIPLE SELECTION POSSIBLE

- ☐ Caucásica (Apis melífera caucasica)
- ☐ Italiana (Apis melífera ligustica)
- ☐ Africanizada (Apis melífera alansoni)
- ☐ Carniola (Apis melífera carnica)
- ☐ Melipona eburnea

- [ ] Melipona indecisa
- [ ] Híbrido
- [ ] Otros
- [ ] No lo sé

9 Productos que obtiene de su actividad: MULTIPLE SELECTION POSSIBLE

- [ ] Miel
- [ ] Polen
- [ ] Cera
- [ ] Colonias vivas
- [ ] Propóleo y/o geopropóleo
- [ ] Jalea real
- [ ] Apitoxína
- [ ] Material biológico
- [ ] Otro

10 ACTUALMENTE: ¿Cuántas colonias VIVAS tiene usted? NUMBER Entry

11 EN ESTA OCASIÓN: ¿Cuántas colonias se murieron? NUMBER Entry

12 La colmena que murió era:

- [ ] Apicultura
- [ ] División (Meliponicultura)
- [ ] Caja madre (Meliponicultura)

13 ¿Cuál era el estado de salud de la colmena que murió? TEXT Entry

14 En su opinión: ¿A qué se debió la muerte de sus colmenas? MULTIPLE SELECTION POSSIBLE

- [ ] Problemas climáticos y/o ambientales (ej. sequía, invierno frío, lluvia excesiva, heladas, incendios, inundaciones)
- [ ] Problemas por contaminación (ej. exposición a químicos/pesticidas)
- [ ] Problemas nutricionales (falta de recursos florales)
- [ ] Problemas sanitarios (enfermedades, ataques por otras abejas parásitas, insectos, animales, plagas etc.)
- [ ] Problemas de manejo (falta de visitas al apiario, tratamientos, suplementos)
- [ ] Robo o destrucción

- [ ] Pérdida por evasión (enjambrazón/fuga)
- [ ] Otras causas

15 En caso de reportar muerte por factores climáticos y/o ambientales, ¿cuál fue el motivo?

- [ ] Sequía
- [ ] Invierno frío
- [ ] lluvia excesiva o inundación
- [ ] Heladas
- [ ] Incendios

16 En caso de reportar muerte por contaminación, ¿qué cultivos se encuentran a los alrededores? En caso de reportar muerte por contaminación, ¿qué pesticidas/químicos sospecha que fueron utilizados? TEXT ENTRY

17 En caso de reportar muerte por problemas nutricionales, ¿cómo considera la falta de recursos florales?

- [ ] Alta
- [ ] Media
- [ ] Baja

18 En caso de reportar muerte por problemas sanitarios, ¿cuál de estos problemas posiblemente causó la muerte de sus colmenas?

- [ ] Varroa
- [ ] Nosema
- [ ] Enfermedades de la cría
- [ ] Problemas con la reina (postura reducida, muerte, colonias zanganeras)
- [ ] Ataques por otras abejas, parásitas, insectos, animales, plagas

19 En caso de reportar muertes por problemas de manejo ¿cuál de los siguientes motivos es posible causante de la muerte?

- [ ] Falta de visitas al apiario (problema de tiempo)
- [ ] Falta de tratamientos
- [ ] Falta de suplementos
- [ ] Problemas de conocimiento sobre manejo
- [ ] Problemas económicos para comprar tratamientos, suplementos, etc.

20 ¿Cómo considera la posible pérdida que ha experimentado este año?

- [ ] Muy importante
- [ ] Importante
- [ ] Normal
- [ ] Poca
- [ ] Muy poca/sin pérdida

Añada aquí una foto de las colonias muertas (no es obligatorio): PHOTO Entry (from camera or gallery)

Disclaimer:

Los resultados de esta herramienta están disponibles en el sitio web del proyecto en cualquier momento. Muchas gracias por su ayuda.

Annex II: Interview Transcripts

Questions for Ecuadorian Beekeepers Regarding 'ECU Polinizadores'

Respecto a las preguntas de la encuesta:

¿Cree que la encuesta contiene preguntas precisas y adecuadas?

- (F) Cuando hablamos de apicultura tendríamos que solo ponerlas las racas que existen: la Africaniza, la Carniola, Italiana y conoceros era la apicultura no poner las especies de meliponinos que existen y quería para los otros, para los otros europeo creo o no.
- (M) Pienso que si.

¿Falta alguna pregunta?

- (F) Creo que cuando se reporta perir a colmenas creo que esta bien saber los elementos o las causas por las cuales las colmenas mueran y en qué zona se perdieron porque poner la ubicación exacto reporta, puedo hacer.. la ubicación que y no está. Y tal vez la pregunta puede ser: ¿En que apiario/en qué provincia se reportó/se perdió las colmenas? Cuando se trata de apicultura debería ser no colonias si no directamente colmenas de abejas.
- (M) No.

¿Hay alguna pregunta irrelevante?

- (F) No creo que hay preguntas irrelevantes. No sé si tal vez entre los productos que usted produce, no sería muy irrelevante porque este ... es apicultor listo y se sabe si es un tipo completo o joven entonces.. Los productos no creo que ser relevante.
- (M) No.

¿Cree que las opciones de respuesta relativas a las muertes en las colonias son suficientemente precisas? ¿Hay otros factores que deberíamos añadir?

- (F) Tal vez la pérdida de colmenas también es por mal manejo, por incendios por ejemplo. Y también se pueden perder las colmenas en inundaciones.
- (M) Si. Si.

Respecto a la interfaz de EpiCollect:

¿Es fácil utilizar la aplicación?

- (F) No que estás enciio utilizar la aplicación. Tal vez hacer la más interactiva, puede ser.
- (M) En mi situación si, porque está en inglés y no puedo hacer uso.

Cuestiones de privacidad:

Nos preocupa la recolección de datos sensibles (como la ubicación y el número de colmenas) porque entendemos que podría dar lugar a robos. Una solución es que los api-meliponicultores introduzcan datos de localización menos precisos, por ejemplo, en un radio de 2 km de sus colmenas. ¿Cree que esto sería suficiente para proteger a los apicultores y sus colmenas? ¿Se siente cómodo compartiendo esos datos de localización con el colectivo y la comunidad apícola?

- (F) En cuento la localización de los apieres que fueran afectados a mi me parece relevante quel que poner la ubicación un tanto precisa pero lo que sería importante es ponerle...la provincia o tal vez el canto, la paroc, diegara es el punto digamos dentro de las preguntas.

- (M) No podemos dar el sitio exacto donde están nuestras colmenas por el motivo de que a veces están lejanas y nos pueden roban.

En cuanto al mapa y la visualización:

¿Cree que el mapa es útil?

- (F) El mapa es útil siempre cuando este uno reporte sus datos de la ubicación que y no está, pero si por ejemplo por cuestiones de tiempo uno se moviliza a otro lado y ponga una ubicación de... tiene los datos después, entonces sai la ubicación no sería tan correcta, habría que buscar es opciones. Porque por ejemplo io estoy exportando una pérdida colmena después que salida la pier y voy a otra provincia entonces me voy a correr los datos en la ubicación de esta provincia.

- (M) Es muy util.

En général:

¿Cree que esta herramienta sería útil para los api-meliponicultores? ¿Para el colectivo? ¿Para la comunidad científica? (Explique por qué)

- (F) Si es relevante conocer las datos porque uno puede con esto de una manera visualizar el tema de la pérdida de colmenas y tal vez es que si el va como antecedente para hacer posible es denunciar, de esas muertes, de los abandonamientos.

- (M) Para los apicultores, si. Para el Colectivo, también es muy útil. Para poder identificar dónde estamos. Para la comunidad científica pienso que es mucho mejor para saber que tipo, que variedad, en cada sector se encuentran ya sean las abejas, apis o las, eeh, como es? Podemos saber dónde se encuentra y en que también podemos encontrar en dónde, en qué clima, en que altitud, se encuentran nuestras abejitas.

¿Tiene algún comentario o contribución para mejorar este instrumento?

- (F) Otro comentario con respecto al tema de meliponicultura: creo que no debería ser tan relevante las especies específicas porque toda no había identificamos correctamente. Lo que sería más estra tar con los géneros, por ejemplo el género melione, el género scaptotrigona, el género tetragonisca, los géneros que el reporting. Y tal vez y fue en términos de comparación con la apis mellifera si es una especie especialmente grande, pequeña o mediana. Que seria mas util que poner nombre científicos porque a veces y la gente los pone solamente por foto porque vio en Brasil, porque vio en otro país, pero no es la especie que está identificada para l'Equador o tiene la distribución en Ecuador entonces ? un poquito de l'equidado.

- (M) Lo primero que yo le he pedido es que esté en castellano. Yo pienso que es super importante para poder identificar y tener un mapa en donde se identifique con claridad y exactitud incluso ahora por medio de la tecnología del GPS nos pueden monitorear desde cualquier parte del mundo.