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Social research in support of a systems-based approach to the environmental risk assessment of multiple stressors in honey bees

European Food Safety Authority (EFSA),
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Abstract

In 2018, EFSA received a request for a scientific opinion from the European Parliament on the science behind the development of an integrated holistic approach for the risk assessment of multiple stressors in managed honey bees (MUST-B). The inclusion of the need to take into account bee management practices in the Terms of Reference of the request, as well as the work being developed to achieve harmonized data collection, have prompted EFSA to undertake targeted social research with the aim of providing an understanding of perspectives of interested parties. Focus groups were held in eight EU countries, selected based on specific criteria, collecting evidence on the beekeepers' understanding of the approach developed under the MUST-B project as an evolution of the current regulation, the needs and expectations in terms of data for managing beehives, digital advancements and requirements for enhanced communication on the topic. With regards to the regulatory system, beekeepers raised some concerns about the current plant protection product regulation, for example in terms of testing and marketing of new products, while appreciating the opportunity to participate in discussions on possible future models. They see the systems-based approach as an ambitious model, having to account for multiple factors; however as a potentially useful system for providing alerts and better knowledge of field situations, when it comes to use of pesticides and bee health. They also stressed the need to understand the combined effects of chemicals. Conditions for data sharing included the need to ensure two-way flow of data between beekeepers and regulators, confidentiality provisions and possible introduction of incentives. The latter was also noted as a pre-requisite for adoption of new technologies in bee management. Beekeepers call for attention of the European institutions, to ensure bee health jointly, including through relevant research such as treatment of Varroa.

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Key words: Honey bees, Multiple stressors, Social research, Focus groups

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Summary

To provide a societal perspective to the systems-based approach for the risk assessment of multiple stressors in managed honey bees (MUST-B), targeted research was conducted among beekeepers in EU to examine the understanding of the proposed approach as an evolution of the current regulation, the needs and expectations in terms of data for managing beehives, digital advancements and requirements for enhanced communication on the topic. A qualitative method – focus groups – was selected as it provides information on attitudes, perceptions, and opinions of participants, obtained through an open discussion led by a facilitator. Such purposive sample, rather than a statistically representative sample of a broader population, elicits more in-depth views on a specific topic, which would be more challenging to obtain through a quantitative method (e.g., survey). A questionnaire was used to guide the discussion.

Focus groups of two to three hours were organised in eight countries. The selection of the countries considered: i) the number of registered beehives as an approximation of the size of the beekeeping activity; ii) representation of different beekeeping landscapes across EU; and iii) pertinence to ongoing efforts in the realm of bee health linked to the MUST-B work (e.g., testing of the ApisRAM) and the systems-based approach developed under the MUST-B project and presented in detail in this scientific opinion. With these criteria in mind, countries selected for the study included Belgium, Bulgaria, Denmark, France, Germany, Greece, Slovenia and Spain.

Beekeepers selected for participation are members of the associations and unions active in each country. A total of 64 beekeepers participated in the discussions, with data collection facilitated through an external contractor.

Analysis was performed by EFSA and its expert group Social Research Methods and Advice. The analysis identified 16 “clusters” of discussion, across four main topics: i) Regulatory system; ii) Data exchange between beekeepers and institutions; iii) Use of digital tools in beehives; iv) Research for bees.

The first topic includes reflections about the capacity of the current regulatory system to protect honey bees, including institutional considerations, testing and compliance. There was appreciation from the community of beekeepers for the opportunity to participate in discussions on possible future approaches.

The second topic focuses on the data exchange and the systems-based approach which was acknowledged as ambitious. It was deemed as a useful system for providing alerts and better knowledge of field situations. Beekeepers stressed the need to set up a two-way flow of data between beekeepers and regulators, while ensuring confidentiality provisions are in place.

The third topic includes opinions on digital tools, such as those that can provide real-time data on status of hives and detection of health problems which was seen as an advantage. Incentives were seen as a pre-requisite for adoption of new technologies in bee management.

The fourth and last topic focuses on the research that can help protecting honey bees. In this regard, beekeepers call for attention of the European institutions, to ensure bee health jointly, including through relevant research such as the need to understand the combined effects of chemicals and treatment of Varroa.

This work is the first case in EFSA’s history to integrate input from the social sciences, in the form of targeted research within current risk assessment approaches. The input provided from this field is significant, allowing the perspectives of interested parties to be considered. EFSA risk assessment methodologies should be extended to include stakeholder views when relevant, contributing to the building of trust in the science underpinning the risk analysis process in the EU. In addition, social research in support of risk assessment approaches may highlight the need for targeted communication to stakeholders in areas of their interest or where further information is needed to clarify the approaches.

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1. Introduction

In 2018, EFSA received a request for a scientific opinion¹ from the European Parliament on the science behind the development of an integrated holistic approach for the risk assessment of multiple stressors in managed honey bees (MUST-B). MUST-B focuses on three pillars: (i) the development of tools and methodologies for the risk assessment of multiple stressors in bees at the landscape level, (ii) the gathering of robust data (i.e. harmonized and standardized) for evidence-based risk assessment of bee health and (iii) the engagement of stakeholders for harmonized data collection and data sharing in Europe on bee health.

The inclusion of the need to take into account bee management practices in the Terms of Reference of the request, as well as the work being developed to achieve harmonized data collection, have prompted EFSA to bring social science skills to the interdisciplinary mix of expertise working together on this project. In line with EFSA's Social Science roadmap (EFSA, 2019), targeted social research was commissioned to provide understanding of perspectives of interested parties and thus strengthen engagement and communication with target audiences.

Following the joint discussions of MUST-B and Social Research Methods and Advice working groups, EFSA decided to examine beekeepers' perspective about the vision for a holistic and integrated approach on honeybee colonies health in Europe through a series of focus groups. The intention was to collect evidence on the beekeepers' understanding of the proposed approach, the needs and expectations in terms of data for managing beehives, digital advancements and requirements for enhanced communication on the topic. As such it was set to provide insights for implementation considerations within the scientific opinion.

2. Data and Methodologies

A qualitative method – focus groups – was selected as it provides information on attitudes, perceptions and opinions of participants, obtained through an open discussion led by a facilitator (Krueger, 1988). Such purposive sample, rather than a statistically representative sample of a broader population, elicits more in-depth views on a specific topic, which would be more challenging to obtain through a quantitative method (e.g. survey).

The focus groups were set to be conducted through an external contractor (ICF Consulting), in a selection of EU countries, based on the following criteria:

- Number of beehives and beekeepers across EU countries - an approximation of beekeeping activity²;
- Different beekeeping landscapes (EFSA, 2017);
- Pertinence to ongoing efforts in the realm of bee health.

Applying a mix of the above criteria, eight countries were selected as per Table 1.

Table 1: Countries included in the research and reasons for inclusion.

Country	Reasons for including in the study scope
France	<ul style="list-style-type: none"> • Southern landscape • Countries with large beekeeping activity (Spain, Greece, France) • Pertinent to EU bee management digitalization work (Bulgaria)
Greece	
Spain	
Bulgaria	
Belgium	<ul style="list-style-type: none"> • Central landscape • Country with large beekeeping activity (Germany) • Pertinent to involvement in Bee hub proof of Concept from EU Bee Partnership (Belgium)
Germany	
Slovenia	
Denmark	<ul style="list-style-type: none"> • Specific bee sub-species as part of the landscape (Slovenia) • Northern landscape

¹ <http://registerofquestions.efsa.europa.eu/roqFrontend/questionLoader?question=EFSA-Q-2018-00645>

² <https://ec.europa.eu/info/food-farming-fisheries>

- Pertinent to EFSA’s testing of ApisRAM model

EFSA compiled a list of beekeeper organisation contacts through its stakeholder and institutional partner network, which were then used by an external contractor to engage with beekeeper associations and ask for their support in recruiting focus group participants. For each focus group, between 5 and 12 participants were recruited (average 8 per group).

Focus groups were conducted in each of the eight countries in scope, between December 6, 2019 and February 20, 2020. Each focus group was run in the language of the country and led by a facilitator who was fluent or native in both this language and English. The sessions ranged in length between 1h30 to 2h50.

EFSA provided a focus group interview guide (see Annex A), covering four main topics:

1. **Regulatory system:** Beekeepers' views of the current regulatory system as well as the proposed systems-based approach to the environmental risk assessment of multiple stressors in honey bees;
2. **Data exchange between beekeepers and institutions:** Beekeepers’ views and concerns regarding sharing of their data, and types of information they would like to receive from the systems-based approach;
3. **Use of digital tools in beehives:** Beekeepers’ uses of digital technologies, and their thoughts / concerns about further diffusion of such technologies in the future;
4. **Research for bees:** Beekeepers’ thoughts on priorities for research in the sector and how they would best like to receive this information.

All focus groups were recorded, with the consent of participants. Recordings were used to generate automated transcriptions, which were then translated into English. The contractor provided both original and translated transcripts to EFSA. Analysis was done by EFSA and its expert group *Social Research Methods and Advice*.

The analysis identified 16 “clusters” of discussion, across the four main topics noted above (see Table 2). The results are presented and discussed according to the clusters.

Table 2: Topics and related clusters of discussion covered in the focus groups.

Topic	Clusters of discussion
Regulatory system	<ul style="list-style-type: none"> • Involvement of beekeepers in pesticide regulation and level of awareness • Efficacy of pesticide regulation (in providing protection from harmful effects of pesticides): compliance, exemptions/derogations • Testing and marketing approval of pesticides: adequacy for grasping effects of pesticides in the “real world”, ways to improve testing • State of beehives and bees in general • Action to support beekeeping, beyond existing regulation
Data exchange between beekeepers and institutions	<ul style="list-style-type: none"> • Potential positive contribution of the systems-based approach to the current situation in beekeeping • Reliability of results from the systems-based approach: Ability of the systems-based approach to adequately deal with complexity of real conditions and very abundant data • Reliability of results from the systems-based approach: Quality of data inputs to the systems-based approach • The systems-based approach: usefulness / useful (or not) data for beekeepers • The systems-based approach in its political context: its positive and potentially negative impacts • Conditions for sharing data (or not)

Use of digital tools in beehives	<ul style="list-style-type: none"> • Usefulness of digital tools in beekeeping • Potential useful data from digital devices • Acceptability of digital devices in beekeeping
Research for bees	<ul style="list-style-type: none"> • Research needs • Conditions for a research relevant for beekeepers

3. Assessment

3.1. Regulatory system

3.1.1. Involvement of beekeepers in pesticide regulation and level of awareness

Three ideas summarise beekeepers' statements about their involvement in regulation:

- A perceived misbalance between institutional consideration given to beekeeping when compared to the chemical and agricultural industries. Beekeepers' feel disadvantaged, with their calls for action for protecting bees actioned upon and considered mostly in times of increased media attention.
- A call to European and national institutions to trust and pay attention to beekeepers' observations about the state of their hives, but also to better inform them about regulations that concern them directly.
- A positive sentiment towards EFSA's initiative to involve them in the development of MUST-B and elicit their views about current difficulties in beekeeping and opportunities for improving the health of honeybee colonies in Europe.

3.1.2. Efficacy of pesticide regulation (in providing protection from harmful effects of pesticides): compliance, exemptions/derogations

"Good regulation, bad control", such could be – in the words of one of the interviewed beekeepers - the summary of most views on current regulatory measures on pesticides. Among the eight groups, Slovenia stood out by its positive appreciation of the regulatory efficacy. In Slovenia, participants underlined the ability of the national authorities to implement trainings on correct use pesticides, by inspecting their activity, by controlling sales of pesticides and by intervening efficiently as soon as effects on honey bees are identified, for finding the origin. Slovenian beekeepers are considered well organized and with important political influence, and people in general are aware of the importance of protecting pollinators.

In all the other groups, pesticide regulation was often perceived as lacking capacity to protect honey bees. The pitfalls perceived were related to both product's toxicity and undue exposure of honey bees. In beekeepers' views, the first comes from sub-optimal testing procedures leading to inappropriately approving molecules for marketing. The second is related to unauthorized use of pesticides, such as sprays during flowering or during unsuitable meteorological conditions, as well as use of banned products. In beekeepers' opinion, training for agricultural actors needs strengthening and their awareness about potential damage to beneficial fauna needs to be raised further. Perceived lack of awareness and institutional provision of relevant controls and penalties inciting at regulatory compliance contributed to such sentiment. In their views, penalties could target those for which non-compliant behaviour is detected. Beekeepers argued that, in some cases, 'non-compliance'³ in the use of PPPs can even occur following national derogations for using EU-level banned neonicotinoids. Some beekeepers regret that spraying at night is not encouraged and generalized in Europe.

For beekeepers it seemed unrealistic to obtain on their own the consideration of the regulation or compensation when bee health gets compromised. Proving the origin of such events seemed highly

³ In this context 'non-compliance' describes the views of beekeepers when it comes to use of PPPs. It does not in any way refer to national derogations (be they for EU-level banned/restricted neonicotinoids or for other EU-level banned/restricted active substances) which are provided for in the regulatory system (Article 53 of 1107/2009).

complicated by lacking ability to get access to and demonstrate the use of a pesticide at a particular moment. Costly legal action was seen as both worsening beekeepers' relationships with other actors and lengthy, with uncertain results. Furthermore, farmers themselves are operating in a set agricultural model, rather than individually deciding about products to use or not, therefore opposing beekeepers and farmers was considered as a neither productive nor desirable outcome.

Bees provide an essential role for agriculture, pollination, and without them *"there is no primary sector"*, as reported by the interviewees. Beekeeper collective boycotts of certain agricultural areas to refuse their pollination have been evoked, with important consequences on the production of the areas concerned. Many beekeepers suggested that protecting bees, farmers and consumers will be possible only if a profound change takes place, i.e. in the medium- and long-term synthetic pesticides are reduced and ultimately completely abandoned in agricultural practices.

3.1.3. Testing and marketing approval of pesticides: adequacy for grasping effects of pesticides in the "real world", ways to improve testing

Regulatory procedures for testing new pesticides for their risks for honey bees before marketing was the most discussed item across most of the focus groups. The majority of interviewed beekeepers expressed their concerns about current testing patterns, along other methodological aspects. The parameters considered in current tests and their focus on acute lethality was often contested, given the potential chronic effects of continuous exposure of honey bees and bee brood to sublethal doses of pesticides.

Arguments in support of such sentiment included:

- Long-term effect of chronic toxicity on bee mortality, as well as sublethal effects leading to delayed health weakening and premature death. Losing 50% of bees was deemed not acceptable as a threshold for deciding on toxicity.
- Laboratory conditions perceived as detached from the reality of bee colonies in terms of their social behaviour and interactions, temperature of laboratory testing and other parameters, such as honey bees' use of contaminated water.
- Protocols for field-testing seen as non-representative for the heterogeneity of the real-world situations that honey bees encounter, and only providing a very partial one-moment-in-time one-location few-hives image of potential toxicity.
- One spot testing, which cannot account for historical contaminations of the soil, the wax, the pollen and even of honey bees' bodies since their very birth, which can lower their tolerance to toxic molecules in their environment.

For all these reasons, beekeepers stated that independent testing, close post-marketing monitoring and shortening review periods from 7 to 5 or even 3 years should be considered, to confirm or not the results allowing to put a pesticide on the market, with suspension of marketing authorization envisaged in case of negative results.

In several groups, the lack of application of EFSA Bee guidance (2013) was mentioned, in discussions related to pesticide-based farming patterns continuing despite their impacts on honey bees and insects in general. Another example was the "test of no comeback to the hive" - not yet adopted for inclusion in the pack of regulatory tests needed for marketing authorization, even if available for a period of almost ten years. Attribution of testing responsibilities to pesticide manufacturers themselves is in the view of beekeepers a challenge in terms of prevailing commercial interest – with a perception of less consideration given to the beekeeping sector.

3.1.4. State of beehives and bees in general

Except for Slovenia, the state of the hives was often described as deteriorating over the past 30 – 40 years, a situation that results in breeding and keeping bees and queens *"getting harder every year"*. As an example, queens are said to live much shorter, about one year, compared to four to five years just few decades ago. Some beekeepers also mentioned qualification requirements for drones (father

colonies). Furthermore, the density of bee populations inside the hives looks lower, just like bees would live less time. In beekeepers' views, honey production per hive is continuously decreasing and mortality remains steadily high in many apiaries, up to 30 and even 50% over one year. Therefore, hives need heavier interventions than before to stay alive, like using high quantities of syrup, which might lead to negative health consequences for the bees, and a much closer management.

The nature of the plant protection products to which bees are exposed also changed during the last decades: while before the mortality was more "visible" (*"dead bees in front of the hive"*), current products are perceived to lead to progressive weakening of hives and circulate all over, including mountain areas, probably with the water particles and rain. Analyses of pollens brought by bees to the hive confirm their heavy pollution with multiple contaminants.

3.1.5. Action to support beekeeping, beyond existing regulation

Beekeepers called policymakers to take them and beekeeping seriously, in the interest of agriculture, honey consumers and bees in general. To support the beekeeping sector, political action is needed on the production side – with adapting subsidies to beekeepers' needs (as for other breeding sectors such as cows or pigs), lowering or even eliminating taxes, and providing a framework for better professional training. Establishing a pollination allowance has been evoked, in recognition of the service that bees bring to agriculture, but there was also fear about potentially unsuited political design of such subsidies, with destructive effects on beekeeping. In focus group participants' views, these measures need to be accompanied by strict controls of the honey market, to avoid frauds. Adulterated honey was mentioned as an example, some of which is imported from third countries. Carefully strengthening the quality of this market, through labelling and stricter rules about what can be sold as "honey", could avoid artificial and unfair losses of revenues due to lowering prices.

Such measures could work hand-in-hand with campaigns for informing consumers and helping them avoid adulterated honey. This could be done through supporting beekeepers' associations that could provide appropriate information and develop educational tools. Beekeepers consider such measures to be urgent for saving the beekeeping sector (and the honey bees together with it), which is facing on the one side increasing costs due to continuous weakening of their hives, and on the other side decreasing benefits due to falling prices associated to importation of low-quality honey. A stronger beekeeping sector might thus be able not only to continue to take care of Europe's bees, but also to ensure a higher percentage of the European honey consumption, which is currently partly imported due to insufficient local offer.

3.2. Data exchange between beekeepers and institutions

3.2.1. Potential positive contribution of the systems-based approach to the current situation in beekeeping

For beekeepers, the most important contribution of the systems-based approach to the existing situation would be in terms of a better knowledge of field situations, by accounting for the heterogeneity of landscape conditions in Europe and the heterogeneity of different beekeeping situations. There is hope that the systems-based approach could serve one day as an alert system, allowing beekeepers to continuously stay informed about the global situation of honey bees in their country and even in Europe and get instant information about potential poisoning events in their vicinity and highly infectious disease such as American foulbrood. To respond to this need, the systems-based approach should stay independent from any commercial or political interests.

3.2.2. Reliability of results from the systems-based approach: Ability of the systems-based approach to adequately deal with complexity of real conditions and very abundant data

By recognizing that numerous factors can influence the health of their colonies, beekeepers acknowledged that building a model to account for the heterogeneity of the situations in the European beekeeping is challenging. There is continuous variation of meteorological and landscape conditions

that can influence directly the colonies' health (e.g., temperature, types and availability of pollen), but also boost or lower the toxic effects of a pesticide and the capacity of bees to respond to it. Beekeeping practices might also vary from one country to another, e.g., very low or very high degree of mobility of hives, some of which can be nomadic. Several substances in the hives or in their environment can interact synergistically. Bees also include several strains (Carnica, Italian, etc....) that might react differently to a chemical. Pesticides can also potentially be used in inappropriate, unpredictable, and unquantifiable ways.

Furthermore, new pesticides can be introduced on the market before getting and modelling the data about the effects of already existing molecules, thus influencing the results. The interactions between all these factors seem complex therefore modelling all this data together seemed challenging to the participants, who questioned if it could really predict causal relationships. According to beekeepers, such a novel approach can certainly produce valuable knowledge, however they are interrogative about its capacity to become a practical, reactive decision-aid tool, given the gap between the urgency to deal with their losses and the potentially long time needed to collect information and validate the results through modelling.

3.2.3. Reliability of results from the systems-based approach: Quality of data inputs the systems-based approach

As a direct consequence of complexity, very large sets of data seem necessary to beekeepers, to cover the heterogeneity of different potential situations encountered in beekeeping (*"then you need sensors everywhere... yes every valley"*). The question of measurement errors has been raised, together with their influence on the quality and usefulness of the whole data set used as input to modelling. Two different ways of collecting input data for drawing an image of colonies' health have been discussed: 1) digital monitoring systems, which would have the advantage of allowing uniform and comparable data along different situations, and 2) observations made by experienced beekeepers along a clear protocol, which would have the advantage of benefiting from their knowledge of bees. While the first has the disadvantage of investments in material and personnel to buy, install, calibrate the instruments and read the data, the second might have the disadvantage of unsystematic individual variation in collecting the data (*"the human factor"*), in absence of training and with too complex instruments.

3.2.4. The systems-based approach: usefulness / useful (or not) data for beekeepers

There is high interest from many beekeepers to have data both on the state of their hives and on the surrounding environment. Having almost instant access to indicators of the health status of their bee population at the time of the inquiry can be useful for adapting management measures to punctual needs and anticipate colony health problems. Contaminants in the hive (wax), in the bees themselves but also brought from the environment (with nectar and pollen), together with the quantity and kinds of pollens introduced to the hive, are considered to be a good indicator of the general state of the hive.

Together, beekeepers would significantly benefit from an early warning or alert system that can be put in place to avert - in the area close to their hive location - about possible toxic events (pesticide sprays, use of new pesticides or at least pesticide groups used in every season), about spreading bee diseases and measures to prevent or treat them, about bee mortalities found by their neighbours, and about any other situation potentially damaging for their bees. That same system could help in individually transmitting mortality events and thus collectively obtaining instantaneous statistics about the state of bee colonies in their region or country. Beekeepers hope that the systems-based approach will be also shaped as a post-authorization monitoring system to inform or confirm effects of newly marketed pesticides on bees in a few-years' time. Knowing if other hives are in the same area was debated - while for some this was deemed useful, others thought it could expose hives to theft.

For some, producing knowledge to protect the environment and the biodiversity was enough for declare their support to the systems-based approach.

If generalized in Europe, beekeepers hope that the systems-based approach and associated documentation will be accessible in national languages. Clear communication adapted to various users

is needed to avoid the black-box effect, which would prevent both understanding from non-specialized users and adhesion to the general vision and objectives of the systems-based approach.

It was unclear for beekeepers how the systems-based approach relates to existing data, and if the very numerous projects and monitoring initiatives having taken place in European apiaries during the last 20 years will be used or not. Lacking coordination between these different data gathering initiatives and failure to use them to get a synthetic view at European level were deplored. Many feared paralysis by analysis – in their views, producing new data about colony health needs to be accompanied by urgent action for limiting the use of pesticides, based on already existing information showing their toxicity on bees.

3.2.5. The systems-based approach in its political context: its positive and potentially negative impacts

In beekeepers' views, the systems-based approach will need to be carefully inserted in European and national institutional frameworks to pursue its objective to support beekeeping and bee health. If the systems-based approach could contribute to identifying cocktail effects when a new pesticide is marketed, this would potentially respond to one of the main challenges of the current regulatory framework.

Whereas accounting for local specificities was considered to be a potentially positive contribution to existing knowledge on bees, the biggest concern for the majority of the beekeepers was that, by using the systems-based approach, the responsibility of pesticides in bee losses may be downplayed by unduly attributing problems to other factors, or by investing time in research about those factors. This in turn could delay diminishing of toxic pressure on the bee colonies.

3.2.6. Conditions for sharing data (or not)

Whereas all beekeepers confirmed their agreement, in principle, with the idea of providing data about their bees, several conditions need to be respected and can be determinant for effective data sharing:

- Results should come back to those who provide their data (*"I want my data report back [...] I don't want the data to go somewhere, disappear"*). Several beekeepers complained about past bee health data collection situations where those collecting – administrations but also academics – did not provide feedback, in some cases even after explicit demand from the beekeeper concerned. Such results would be useful for beekeepers, improving their knowledge about the state of their colonies and about the environment of their hives.
- Business information should stay confidential, similarly to any commercial information for other businesses. Such information includes data about production quantities (honey, pollen, etc.) and sales, which are by the way of low relevance for appreciating the state of the colonies. Confidentiality should also include, for many participants (but not all), data on the location of their hives (for one of them *"beekeeping is like picking mushrooms, the one who knows does not tell anyone where he picks them up"*).
- The biggest concern about sensitive commercial data was related to their potential use by financial services and associated taxation burden. Attitude towards confidentiality varied depending on the country and trust in national and European institutions. Some beekeepers stated that they would give data for a scientific purpose only, provided that a trustful organization guaranteed confidentiality and data use for that purpose only. Some others considered that the best strategy for guaranteeing confidentiality is to avoid giving any sensitive data, as no institution could be fully trusted and so *"financial institutions will one day do something with it"*. Furthermore, if data were to be used for regulatory interventions on beekeeping as a sector of the economy, some expressed doubts about institutions' capacity to do so properly, in the interest of bees and beekeepers.
- Besides its purpose, who has access to data was noted as important criterion. Whereas access by scientists is considered legitimate and potentially useful for the beekeeping, access by non-trusted institutions or by pesticide producing companies might have negative consequences on beekeepers.

- Data on the number of hives is not the most relevant for measuring the state of the bee populations, as beekeepers – particularly professional ones - replace lost colonies each year to be able to continue their activity.
- For some beekeepers, data on diseases might be perceived as self-accusing (i.e., resulting from their own mismanagement) and so difficult to communicate.
- Data on events leading to worsening bee health may be unreported due to lack of conviction that it would be actioned upon, in which case it would only compromise neighbouring farmers.
- Anonymity is not the most important condition for submitting data and should be a choice left open to beekeepers willing to share data. However, confidentiality of non-anonymous submissions should be guaranteed, so that data analysis and access by other users should not allow identification of individual beekeepers.

When significant effort and time is demanded from the beekeeper to collect data for scientific purposes, the expectations are two-fold: either a feedback provided on the health status of their hives, or some sort of remuneration for the invested efforts. Some beekeepers would appreciate expert advice about actions to implement in situation where data points to a problem. Protocols for collecting data should be easy to understand and apply, making them less time consuming for beekeepers.

3.3. Use of digital tools in beehives

3.3.1. Usefulness of digital tools in beekeeping

The respondents felt that usefulness of digital tools depends on the parameters measured. Scales, already used for many years by professional beekeepers, proved their benefits for saving time and money, as they provide information on distant hives that could previously be obtained only by travelling to that location. Data on colony weight informs beekeepers about the honey production, the food needs, or the general status of the bees. In addition, cameras can be used for protecting from theft. Another example of useful tool was a developing tool aiming at predicting swarming in a hive few days in advance, which allows the beekeeper to get prepared for it.

Besides such simple parameters, more complex data provided by digital tools might not be easy to use by many beekeepers because of the technical competencies needed to interpret them and evaluate what they mean for the colony. For now, complex measurements of colony activity seem to be useful rather for research purposes. The reverse side of digitalization could be losing *"the practical experience reaching out to the old beekeepers, who have a sixth sense of something"*. More generally, there seem to be few perceived benefits from digitalization for hobby beekeepers.

Furthermore, equipping hives with sensors might not be easily adapted to the daily practice in beekeeping, in particular because of bees' tendency to add propolis around objects getting into the hive, but also because of thefts in the rural areas, where apiaries are not under continuous surveillance. There was important concern expressed in several groups about potential effects of electromagnetic fields produced by such digital technologies on the health of the bee colonies.

3.3.2. Potential useful data from digital devices

According to beekeepers, the most useful data from digitalization would be one that helps them at better knowing the status of their hives in real time. Relevant information could include parameters descriptive of the state of the colony, indicative of potential health problems: the total number of bees in the hive, the number of bees getting out and coming back to the hive, the life duration of individual bees on particular crops, alert indicators informing about a pathological condition. All such parameters could be modelled in a system of automated characterization of the state of the hive, based on input data provided by the beekeeper. An example output of such a system could be a functionality to interpret pictures to characterize bee poisoning events.

In addition to these parameters, recordings of bee behaviours - and in particular sounds - could be indicative of potential normal or threatening events: indications about a colony prepared to swarm in the following hours or an alert when hornets are in front of a hive.

3.3.3. Acceptability of digital devices in beekeeping

Adoption of digital equipment raised, on one hand, pragmatic considerations about convenience for beekeepers especially in terms of costs of new technologies and energy consumption and, on the other hand, the topic of beekeepers' attitude towards bees. Regarding costs, suggestion was made these be borne by the EU in case of setting a union-level assessment model.

On the topic of attitudes towards bees, beekeepers noted that, far from being a simple quasi-industrial production tool, bee colonies are the symbol of a way of living in agreement with nature, where humans rather accompany and facilitate the life of bees instead of trying to heavily intervene to adjust and modify it for their economic interest. *"There is fascination about bees' complex organization resulting from millions of years of natural evolution, which humans and their computers can hardly pretend to understand and influence"*. Because understanding is so partial, there is scepticism about digitalization being able to improve the practice of beekeeping and fear that it will create even more problems. For some, traditional beekeeping methods are far more efficient and advantageous for colonies' health than modern ones.

This perspective about the place of humans in nature is determinant for beekeepers' ambiguous attitude towards digitalization. On the one side, they hope improvements in their daily production work from it (for professionals), and even help for improving the state of health of their bees. On the other side, they express doubts about the ability of human technologies to correctly understand and positively contribute to such a complex and well-organized manifestation of life as bee colonies.

3.4. Research for bees

3.4.1. Research needs

Among the research needs having emerged during the discussions, one of the most often evoked is related to ways to better understand and deal with Varroa. An improved understanding would target investigations of causes and situations where Varroa produces important losses, related to the environment of colonies and to their ability to manage infections. Research questions could be: Are there situations and/or environments where Varroa has more impact on colonies than in others? Which factors promote the development of Varroa, and is there a role of pesticides in it? Why do some colonies manage infections relatively well without treatment, whereas others do not? Which are the effects of varroicide treatments on bees and on honey contamination?

In respondents' views, solving the problem of Varroa could be done either through genetic selection (some bee strains being able to deal naturally with it) or with help from new treatments with low toxic side-effects on bees. However, beekeeping being a relatively small market compared to human or other veterinary medicines, companies do not seem to invest in finding a treatment, which beekeepers regret.

Related to last decades' losses, two aspects seem most important to beekeepers. The first is to understand why queens are living much less longer than before, a phenomenon that accompanies a lowering number of bees in the hives. An assumption they suggested to test is that not only queens are affected, but males are also less fertile, which would have direct consequences on sperm survival and egg laying. A second important topic is to better characterize the chronic, sublethal effects of pesticides, in both treated and non-treated remote areas, as well as the paths of dissemination of agricultural pesticides in areas where they are not used, such as mountain areas.

Besides Varroa and pesticides, there was interest in research about the impacts of electromagnetic fields, among which the developing 5G network and high voltage lines, of climate change and of sound waves near wind turbines. More generally, beekeepers asked whether bee populations significantly changed during the last decades, under the pressure of human factors, compared to adaptive evolutions having taken place over millions of years.

The development of quick and inexpensive methods to detect adulterated honey was also mentioned - of direct commercial interest, with indirect impacts on strengthening the European beekeeping sector and thus on preserving bee colonies. A quick test, using "honey fingerprints", could correct the market of honey, currently distorted by fraudulent practices (*"honey mixtures"*), and set the prices at levels favouring good beekeeping practices and consumer protection.

3.4.2. Conditions for a research relevant for beekeepers

There is a feeling among beekeepers that scientists do not interact with them as much as they could, which makes existing academic research both hard to use in practice and partially irrelevant for their needs. Scientists and relevant institutions are called to better communicate and diffuse existing research, but also to involve beekeepers upstream in establishing research topics and protocols in accordance with their needs. Beekeepers welcome the creation of a “hub”, a sort of centralised platform collecting research findings, available in all languages and easy to understand for the wider audience.

Clearly, for all groups, all these research topics need significant financial investment, up to the ecological and agricultural challenges associated to continuously weakening bee colonies. Research should aim at large-scale studies, ideally cohort studies involving a representative number of apiaries using different bee breeds. Research results, regardless if funded by public or private money, should be freely available according to the beekeepers.

4. Conclusions and Recommendations

Involvement of beekeepers is fundamental for putting the systems-based approach in place. With that in mind, a holistic approach must also consider evidence on the beekeepers’ understanding and views on success factors of implementing the approach. Using qualitative and quantitative methods to generate such evidence is among recognised contributions of social research and expertise to the entire risk analysis process (Wendling, 2014).

As highlighted in the Social Science Roadmap (EFSA, 2019), the involvement of social science expertise in the work of scientific groups can provide a societal perspective and, ultimately, improve the quality of EFSA’s outputs. Adding the “social” aspect of scientific excellence is able to strengthen EFSA’s role in the EU food safety system as a trustworthy source of advice on food safety.

This work is the first case in EFSA’s history to integrate input from the social sciences, in the form of targeted research within current risk assessment approaches. The input provided from this field is significant, allowing the perspectives of interested parties to be considered. EFSA risk assessment methodologies should be extended to include stakeholder views when relevant, contributing to the building of trust in the science underpinning the risk analysis process in the EU. In addition, social research in support of risk assessment approaches may highlight the need for targeted communication to stakeholders in areas of their interest or where further information is needed to clarify the approaches.

Although the representation of stakeholders in this study was limited to beekeepers, follow-up and replication for other stakeholder groups can be conducted under related EU-funded projects or through future targeted social research in the context of pursuing a systems-based approach to the environmental risk assessment of multiple stressors in honey bees.

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Annex A – Focus Groups Interview Guide

Background information to share before the Focus Group

- *Intro on EFSA's MUST-B project and EFSA work on bee health – available also in form of a video*
- *Text comparing the current regulatory system with the proposed approach (vision of the new opinion explained in simple language)*

Package 1 – Regulatory system

Facilitator to give a short introduction on the current regulatory framework in Europe

- Is the current legislation in Europe, particularly the one on pesticides, protecting adequately bee health?
- Which are the positive aspects?
- How could it be improved?

Facilitator to give a short presentation on MUST-B (this could include showing the video)

- Now consider the **Vision** proposed by MUST-B - would it support beekeeping as a sector by protecting bee health?

Package 2 - Data exchange between beekeepers and institutions

Providing data might be a reason of concern for some beekeepers who might fear administrative use of that data either for regulatory purposes or for imposing financial obligations.

- Which would be the reasonable conditions for beekeepers to serenely share data with both national and EU authorities? Please share any data sharing concerns, if you have some (*prompt if any difference for data sharing with national authorities as opposed to sharing with EU authorities*)
- Which confidentiality and data protection provisions would allow you to serenely share data?

The current regulatory system might be adapted in such a way that it produces useful data for managing beehives.

- Thinking now about the data that the model would generate - which data would be useful for beekeepers?

(Examples of data to prompt discussion if needed: early warning system connected to selected apiaries (pilot monitoring in EU) in EU delivering real-time data on bee health: personal communications to beekeepers on predictions on resource availability, intoxication probability, infectious agent prevalence, etc.)

Package 3 - Use of digital tools in beehives

Adoption of new technologies, referred to here as digital beehives, may include scales, counting/image processing, sensors (for vibration, temperature, humidity).

- In your opinion, which are the advantages and disadvantages of adopting these technologies?
- If there are concerns, what are they?
- How would adopting these changes change beekeeping? For example, would it affect the way you/beekeepers manage time? Would it disturb hives? Would it impact the quality of life of bees? And would it affect other aspects of your work?
- And beyond your work, would this impact your way of life?
- Is the adoption feasible? In your opinion, how would other beekeepers in <name of country> feel about adopting these technologies?
- How do you see the role of EU in promoting the adoption of new technologies for beekeeping?
- If you could influence innovation on how bee health is monitored, which kinds of IT/semi-automatic tools would you find most useful? What sort of innovation could these tools bring?

Package 4 - Research for bees

This package is meant to prompt individual views of participants on interaction of beekeepers with research rather than test knowledge of beekeepers about research.

- How could the work of researchers help you in your activity? In your view, are there any important questions that are not answered yet?
- If you could influence applied research in the beekeeping sector - more specifically on healthy colonies - which areas would you prioritize?

*(Examples to prompt the discussion **if needed** > ensuring bee-friendly agriculture; assessing exposure to multiple chemicals; applications that give real-time data on the status of colony health)*

- How could researchers and beekeepers interact during research planning and development?
- How can the EU ensure that the research projects it supports are relevant for beekeepers?
- Through which channels could the EU communicate on research progress to beekeepers
(examples of channels > events, newsletters, websites, mobile phone applications)