2nd consultation in relation to the revision of the bee guidance document (EFSA, 2013)

Draft protocol for the scientific assessment of background mortality of bees (*Apis mellifera*, *Bombus* spp. and solitary bees)

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1. Introduction

1.1. Introduction and scope of this protocol

This document illustrates the draft protocol for the scientific assessment of background mortality of three bee taxa (*Apis mellifera*, *Bombus spp.* and solitary bees), which will be used as input for the revision of the EFSA Guidance Document on the risk assessment of plant protection products on bees (*Apis mellifera*, *Bombus spp.* and solitary bees). This draft protocol has been developed with the aim of defining the methods that will be applied for collecting data (i.e. which data to use for the assessment and how to identify and select them), appraising the relevant evidence, and analysing and integrating the evidence in light of the identified uncertainties.

This draft protocol has been developed following the principles and process defined in a project aimed to further improve EFSA's scientific assessment processes (EFSA, 2015)[1] and based on the recommendations for protocol development currently under development by a working group (WG) of EFSA's Scientific Committee.[2]

The protocol is being shared for targeted consultation and will be revised as appropriated based on the feedback from the Stakeholder Group and from experts in the different EU Member States.

1.2. Background and Terms of Reference as provided by the requestor

EFSA adopted in 2013 a Guidance Document on the risk assessment of plant protection products on bees (*Apis mellifera*, *Bombus spp.* and solitary bees) (EFSA, 2013), which so far has not been fully implemented due to some lack of consensus between Member States. For this reason, Member States have requested a review of the guidance document before considering full implementation.

In March 2019, the European Commission has mandated EFSA to revise the aforementioned Guidance Document (SANTE/E4/SH/gb(2019)1623216). This revision should focus on several aspects, for which new scientific evidence may have meanwhile become available. The first of these aspects is "*A review and summary of the evidence as regards bee background mortality, in particular considering realistic bee keeping management and natural background mortality*." In the detailed Terms of Reference of the mandate, EFSA was specifically requested to provide this summary in a separate document from the guidance document.

The present document reports the methodology that will be followed for addressing the specific bee background mortality issue.

[1] http://www.efsa.europa.eu/en/methodology/evidence

[2] Add link to SC mandate/WG on protocol development

2. Problem formulation

This section illustrates how the WG interpreted the terms of reference of this mandate and formulated the scientific questions that will be answered. The latter are also summarised in Table 1 at the end of the section.

2.1. Assessment questions based on the interpretation of the mandate

In both the Guidance Document (EFSA 2013) and in the preceding Scientific Opinion (EFSA 2012), 'background mortality' was intended solely as adult bee mortality. Both documents report several literature values for background mortality for adult bees. Mortality rate of the adult bees has a direct link to the colony strength (defined here as the number of adult bees present at a given time in the colony) and/or to population size, which were previously considered to be the main focus of the protection. In addition, brood mortality has been historically considered as a separate phenomenon, which is only indirectly related to colony strength and/or population size. For sake of consistency, in this new scientific assessment, bee background mortality will consider solely adult bees.

The terms of reference, in describing bee background mortality, mention natural causes together with realistic beekeeping management. Indeed, for managed bee colonies, beekeeping practices may shift the actual mortality in both directions when compared to the natural one.

However, at least for domesticated bees, a full separation between natural mortality and mortality due to human management is not feasible, as any measurement performed on the colony requires a certain degree of human intervention. In addition, managed colonies are not completely natural by definition. While considering this as a starting point, an exploration of the effect on mortality of realistic beekeeping practices will be carried out as well.

2.1.1. Target population

The objective of this assessment is to estimate the background mortality of honey bees (*Apis mellifera*), bumble bees (*Bombus spp.*) and solitary bees. These three groups differ primarily in their biology, but also in the level of domestication and therefore in the effect produced by beekeeping practices. In each one of these groups, as already specified in the previous section, the focus will be on adult organisms.

- European Honeybees (*Apis mellifera*): eusocial bees living in generally large, perennial colonies with a single queen. While existence of wild honey bee colonies in Europe and North America is known, these are rather scarce (Seeley, 2015). For the purpose of the present assessment, only domesticated and managed honey bees will be considered. Honey bees are important providers of a range of products for humans. Hence, beekeeping practices are oriented to maximise the life of the colony for long periods.

- Bumblebees (*Bombus spp.*): most bumblebees species are social, with bees living in annual colonies with a single queen. Generally, only new queens survive the winter season. The colonies are smaller than those of honey bees. Most species are entirely wild, and colonies live in nests underground or in other protected sites above ground (e.g. tree cavities). Nevertheless, some species (e.g. *Bombus terrestris*) have also been domesticated and both wild and managed colonies exist. Managed bumble bees are generally only kept for ensuring effective pollination, but hive products are generally not harvested. Furthermore, colonies cannot survive for more than one active season. Hence, beekeeping practices are limited to maintaining the hive healthy for the season.

- Solitary bees: this group include the majority of bee species, characterised by solitary behaviour. The high taxonomic diversity of this group is reflected in most of the ecological traits: nesting, feeding, and reproduction strategy can be very different. Most species do not have overwintering adults, but there are exceptions. For example, some species of the genus *Osmia* present overwintering adults.

2.1.2. Seasonal and geographical scale

Bumble bees do not present a real adult population during the winter period, as only the new queens survive. Hence, for this group the assessment will focus on the active period from the establishment of the colony (late spring-early summer) until its termination (autumn).

A similar situation is represented by many solitary bee species that overwinter in a larval form. Also in this case, the assessment will consider the active period only: from emergence (generally in spring) until death of the adults (generally in autumn).

However, both honey bees and some species of solitary bees do have a proper overwintering adult population, although this is generally rather inactive. For these species, two different assessments will be conducted with a focus on, respectively:

1) the active period, i.e. when bees are foraging for resources and broods are produced;
2) the overwinter (dormancy) period, i.e. when bees reduce their activity to the minimum and stay in the hive (honey bees) or are enclosed in cocoons (solitary bees).

The assessment will focus on the EU. This will limit the collection of data uniquely to the bee species occurring in EU, i.e. 1900 species according to Nieto et al. (2014), and under conditions representative of any of the EU bio-geographic regions (EEA, 2002). It should be noted that experiments carried out outside of the EU may still be considered relevant, if the study area is a fair representation of any of the EU bio-geographic regions. Bee mortality during the active period is likely to be strongly dependent from the time bees spend foraging. This is in turn strongly influenced by weather conditions, mainly temperature and precipitations. Hence, these two climatic variables will be used to discriminate settings that can be representative for EU conditions during active periods. On the other hand, mortality can be influenced by temperature during dormancy periods. Hence, this variable will be used to discriminate settings that can be representative for EU conditions during dormancy periods. Climatic data from the 9 FOCUS groundwater scenarios (considered to cover most of EU conditions were agricultural activities are taking place, see below consideration on the landscape) were extracted from the software appDate 2.0 (Klein, 2012). These daily data covering a period of 20 years had been average by month, producing 2160 datapoints (12 months*20years*9scenarios). These had been separated into two classes, indicating the "active" and "inactive" (i.e. dormancy) period. The scenario-specific month where crops starting emergence was considered the as the start of the active period, while the last month of harvesting was taken as its end. The "admissibility area" for the active period is determined by the 5^{th} and the 95^{th} percentiles of the temperature and rainfall calculated as described above. i.e. a study carried out outside of the EU will be considered suitable if the point determined by the average temperature and precipitation amount will lay in the "admissibility area".

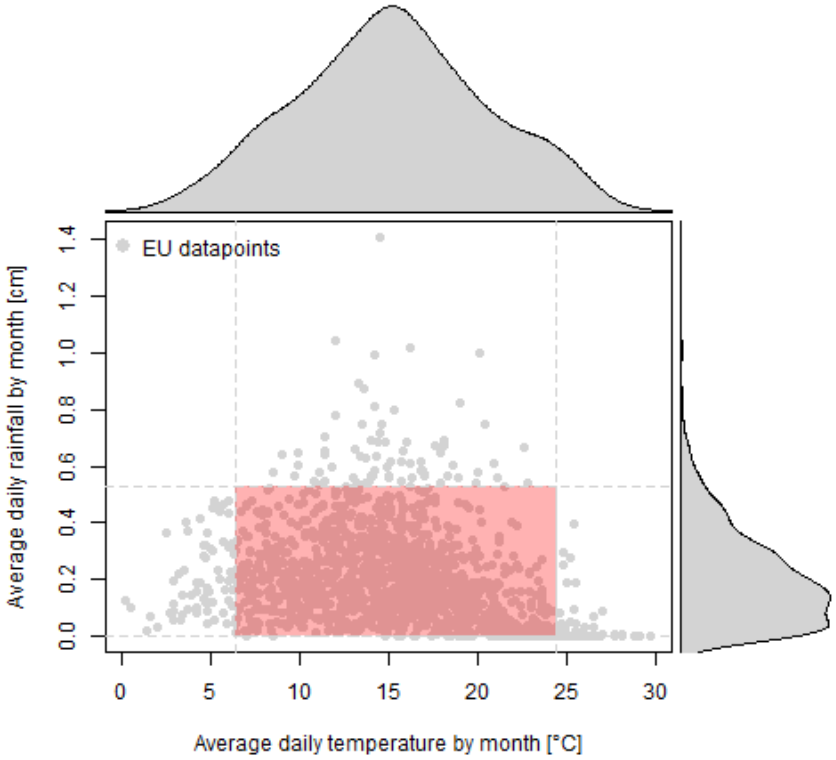

Figure 1: Representation of the "admissibility area" (active period) determined by average temperature and rainfall, that allows identifying studies carried out outside of the EU but still considered a fair representation of EU bio-climatic conditions.

For the dormancy period, the logic will be similar, but one-dimensional, as the only relevant variable is temperature.

The general framework of this activity is the revision of the risk assessment scheme of plant protection products on bees. Therefore, the present assessment will investigate conditions that can be assumed as an appropriate benchmark, i.e. where application of plant protection products is more likely to occur. As such, data are considered relevant when referred to representative European agricultural landscapes. This means that:

1) The study area should be mainly occupied by croplands and/or orchards.
2) The crop in the area should be dominated by crops/orchard grown in the EU.

2.1.3. Definition of background mortality and related relevant endpoints

For this assessment, background mortality is defined as the combination of natural mortality and, for managed bees, mortality induced by realistic beekeeping practices. Considering the present context, background mortality can be defined as mortality due to any aspect that is independent from accidental exposure to pesticides.

The cause of mortality can therefore be 1) fully natural (e.g. aging, predation, naturally spreading diseases, adverse weather conditions, natural starvation and, for social species, natural loss of orientation), 2) not directly linked to beekeeping practices, but still related to human activities (e.g. starvation due to food shortage in heavily managed landscape,

spreading of diseases from managed bees to wild bees, competition between managed bees and wild bees, predation from alien species introduced via human activities, exposure to pollutants other than pesticides) or 3) directly induced by beekeeping practices (e.g. mechanical manipulation of the combs/hives/boxes, adverse conditions during colony displacement, starvation due to excessive honey harvesting, exposure to in-hive chemicals).

Within this document, bee background mortality is generally intended in terms of rate (e.g. percentage mortality over a certain time period). Ideally, bee background mortality is expressed in terms of a daily rate (daily percentage mortality), in order to account for the dynamicity of colonies and populations. In less dynamic conditions (e.g. winter dormancy periods) mortality can be expressed as rate over a longer period (e.g. percentage of mortality over the winter season). However, when exploring the effect of beekeeping practices, mortality may not be related to a particular lag time (i.e. more or less instantaneous). In this case mortality will be considered as an unknown quantity in a certain instant, without consideration of time (i.e. percentage of mortality).

There are several possible measurable parameters (endpoints) that can be used to quantify bee background mortality. A presentation of those that are currently foreseen to be the most relevant is reported below, along with the related assumptions and uncertainties:

1. Bee longevity (all types of bees)

EFSA (2013) estimated bee background mortality rate by using the reciprocal of bee longevity. While this outcome is certainly relevant, some considerations are in order:

- Bee longevity is unlikely to be constant over the active period. For honey bee workers some authors suggested that the lifespan is strongly influenced by the foraging effort (Neukirch, 1982) and foraging effort is in turn unlikely to be constant, as it depends from many external conditions (weather, food availability, distance from food sources, etc.) that vary in time. The level of the resulting mortality rate of the colony is also unlikely to be constant, because of the change in colony strength (increasing at the beginning of the active period and decreasing at the end). Nevertheless, the reciprocal of bee longevity observed under specific conditions is a suitable proxy for estimating the mortality rate for those conditions. It should be noted that this applies to all social bees, while it is less of an issue for solitary bees.

- Some studies focussed uniquely on the foraging lifespan of honeybees, i.e. last part of a worker honeybee life cycle. However, in order to extrapolate from forager mortality rate to the entire hive mortality rate, some considerations are needed in terms of in-hive bees:foragers ratio. If this ratio is known and remains more or less constant, it might be possible to perform the extrapolation, by assuming that the in-hive workers (e.g. nurses) have a negligible mortality compared to the foragers (Dukas, 2008; Rueppel et al., 2007).

2. Direct estimation of forager bee mortality

Some studies may be able to investigate the actual number of bees which leave the hive/nest at a certain time and do not come back. When this happens, there is a very high chance that the bee had died. Studies using several tagging techniques (colour tags, electronic tags, etc.) can be used for this purpose. The ratio of lost bees to total tagged bees is the mortality percentage, which can be expressed as a rate by accounting for the length of the observation period.

3. Indirect estimation of mortality via monitoring of hive/nest parameters

The number of adult bees at any moment t is determined by the number at t - 1, plus the newly emerged bees minus the bees dying in the Δt (between t - 1 and t). Therefore, at least in principle, a continuous monitoring of the colony/population strength together with a continuous count of newly emerged bees could provide an indirect estimation of bee mortality. In reality, this approach has some important practical limitations.

For bees organised in colonies, such a continuous monitoring requires that the hive/nest is inspected rather frequently, and that the status of brood cells is recorded each time. This practice is very invasive, and it is considered that most field studies will not provide suitable information for estimating background mortality via monitoring hive/nest parameters. Experiment investigating pesticide effects on honey bees and bumble bees present the same issue. While the unexposed control could in principle be used for estimating background mortality, in practice it is considered that the available information will be unsuitable for the present purposes.

Some species of solitary bees (e.g. *Osmia spp.*) are univoltine (Sgolastra et al. 2019), and the adult population in the active period – once the emergence form the cocoons is finalised – is not affected by emergence of new bees. Hence, in this case, any change (i.e. decrease) in the population abundance should be directly linked with mortality. Population abundance can be estimated, for example, via monitoring the occupancy of nesting units in time. Other solitary bee species may have more than one generation per year, therefore a proper estimation of the mortality should monitor emergence from brood cells as well. Nevertheless, this monitoring may be performed in a less invasive manner than for social bees (i.e. honey bees and bumble bees).

4. Pre-post winter colony strength (honeybees only)

During winter honey bees generally do not produce new broods. Hence consecutive measurements of colony strength in this period offer an immediate estimation of the mortality. While having hive inspection during the winter is unlikely, measurements of colony strength (i.e. number of adult bees) just before the beginning of the inactive period (i.e. before hives are closed) and just after the end of the same inactive period are not rare in long-term monitoring studies. The difference of these two figures can provide a reliable picture of the overwintering mortality rate, where the time interval is the entire inactive period.

5. Emergence failure (solitary bees overwintering as adults only)

For those species of solitary bees that overwinter as adults enclosed in cocoons, the mortality could be assessed as the emergence failure ratio (number of bees that do not manage to emerge from the cocoons over the total number of cocoons).

6. Recorded in-hive mortality after specific practice (managed bees only)

Specific beekeeping practices may cause peaks of the in-hive bee mortality and some studies investigating such effects (e.g. counts of dead bees) may be available. In this case the mortality is to be considered event-driven and it may be more appropriate to express it in terms of static fraction (i.e. dead bees/total bees) rather than a rate. While this applies to all managed bees, it is foreseen that the relevance for bumble bees is more limited, as 1)

beekeeping practices are more limited; 2) the colony cannot always be fully inspected without disrupting it.

265 **Table 1. Summary of the questions that will be answered in this scientific assessment**

Question	Population	Geographical scale	Seasonal scale	Background mortality and relevant endpoints
1a What is the all-causes[3] background mortality, preferably expressed as daily percentage rate of adult honey bees in EU, during the *active period*?	European Honeybees (*Apis mellifera*) (adults)	EU	Active period [spring-autumn included]	All-causes[3] background mortality measured based on the following parameters: • Bee longevity • Direct estimation of forager bee mortality • Indirect estimation of mortality via monitoring of hive parameters
1b What is the all-causes background mortality, of adult honey bees in EU during *winter*?	European Honeybees (*Apis mellifera*) (adults)	EU	Overwinter (dormancy)	All-causes[3] background mortality measured based on the following parameters: • Pre-post winter colony strength (honeybees only)
2 What is the all-causes background mortality, preferably expressed as daily percentage rate of adult bumble bees in EU during the active period?	Bumblebees (*Bombus spp.*) (adults)	EU	Active period [spring-autumn included]	All-causes[3] background mortality measured based on the following parameters: • Bee longevity • Direct estimation of forager bee mortality • Indirect estimation of mortality via monitoring of hive/nest parameters
3a What is the all-causes background mortality, preferably expressed as daily percentage rate of solitary bees in EU during the active period?	Many species of solitary bees (adults)	EU	Active period [spring-autumn included]	Background mortality (fully natural or not directly linked to beekeeping practices, but still related to human activities) measured based on the following parameters: • Bee longevity • Direct estimation of forager bee mortality • Indirect estimation of mortality via monitoring of nests occupancy
3b What is the all-causes background mortality, preferably expressed as daily percentage rate, of adult solitary bees in EU in winter?	Some species of solitary bees (adults)	EU	Overwinter (dormancy)	Background mortality (fully natural or not directly linked to beekeeping practices, but still related to human activities) measured based on the following parameters: • Emergence failure

[3] All-causes mortality can be 1) fully natural, 2) not directly linked to beekeeping practices, but still related to human activities and 3) directly induced by beekeeping practices (see section 2.1.3).

Question	Population	Geographical scale	Seasonal scale	Background mortality and relevant endpoints
4 What is the mortality due to specific beekeeping practices, preferably expressed as percentage of total colony, in adult honey bees in EU?	**Managed** European Honeybees (*Apis mellifera*) (adults)	EU	All year	Mortality directly induced by beekeeping practices, measured based on the following parameters: • Recorded in-hive mortality after specific practice
5 What is the mortality due to specific beekeeping practices, preferably expressed as percentage of total colony, in adult bumble bees in EU?	**Managed** Bumblebees (*Bombus spp.*) (adults)	EU	All year	Mortality directly induced by beekeeping practices, measured based on the following parameters: • Recorded in-hive mortality after specific practice

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3. Methods for collecting and assessing data

An overview of the methods that will be applied for collecting and assessing data on the questions illustrated above is provided in table 2 and detailed in the following sub-sections.

In the table, the methods are summarised together for simplicity; however, it is important to outline that they refer to separate assessments.

Table 2. Outline of methods for collecting and assessing data on background mortality for honey bees, bumble bees and solitary bees

Questions resulting from the translation of the mandate (see table 1)	Method for collecting and assessing data
Questions 1a, 2 and 3a (seasonal scale: active period) (three separate assessments, one for each bee species) Questions 1b and 3b (seasonal scale: winter) (two separate assessments, one for each bee species)	**Data collection**: • Extensive literature searches • Data submitted to or collected by EFSA in the context of the last evaluation of three neonicotinoid substances (EFSA, 2018) • Structured study selection process based on pre-defined eligibility criteria for study inclusion/exclusion • Structured data extraction process from studies included in the assessment **Evidence appraisal**: • Structured appraisal process, using pre-defined critical appraisal tools (CATs)
Questions 4 and 5 (managed honey bees and bumble bees) (two separate assessments, one for each bee species)	**Data collection**: • Extensive literature searches, • Structured study selection process based on pre-defined eligibility criteria for study inclusion/exclusion • Structured data extraction process from studies included in the assessment • If sufficient evidence is not found via literature searches: information collected via survey sent to beekeepers (for honey bees only) • Survey distribution by involving national beekeeper associations of at least 10 European countries covering all 3 regulatory zones • Minimal nomination of 10 professional/industrial and 10 amateur bee keepers per country • Questions on: number of bee hives; location of bee hives; 20 specific bee keeping practices; frequency of larger incidence (>100 dead bees following the application of a specific practice)

Questions resulting from the translation of the mandate (see table 1)	Method for collecting and assessing data
	Evidence appraisal: Structured appraisal process, using pre-defined critical appraisal tools (CATs) **Survey:** Online survey tool using individual invitations

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3.1. Methods for collecting data

3.1.1. Eligibility criteria for study selection

The criteria for selecting studies on background mortality for the three bee species during their active period and over winter (questions 1-5) are reported in tables 3-6 in this section.

These criteria will be used to decide on study inclusion or exclusion, regardless of the study source (e.g. open literature or dossiers submitted to EFSA).

Table 3. Criteria for selecting studies for questions 1a, 1b and 4 (*Apis mellifera*)

Study design	**In**	Field studies [Performed in open settings where the variables naturally occur with minimal direct influence of human. In field studies, the bees are free-flying, exposed to any stressor due to their natural activity. Unavoidable intervention by the beekeepers (for managed bees) may take place]
	Out	Lab studies Semi-field studies Colony-feeding studies (even if field design) Modelling/in-silico studies
Population	**In**	European Honey bees
	Out	Rest of bees, other animals, etc.
Exposure	**In**	Natural/Normal [No excessive exposure to anthropogenic effects, which may cause elevated mortality (e.g. fields surrounding the hive treated with insecticides). Note that bees may still be exposed to anthropogenic effects e.g. to chemicals that are normally used in agricultural landscapes. As long as the levels of these stressors are considered as comparable with the usual background level, the study is considered as eligible]
	Out	Specific exposure to a stressor outside of background range [When an anthropogenic stressor is considerably higher (even temporarily) than the usual background level, the study or that experiment is considered as non-eligible. For example, if a study is specifically done for assessing the effects of an exposure to a chemical, the treatment part should be left out]
Outcome	**In**	Information on background mortality (not necessarily as primary outcome): Acceptable methods for assessing background mortality: - Measure of the lifespan (longevity) of the bee. - Direct estimation of forager mortality via tagging of individual bees. - Estimate of winter mortality by measuring colony strength before and after winter. - Mortality is assessed indirectly by monitoring the population in the hive together with the brood production (unlikely to provide suitable information due to practical limitations).

		Information on mortality caused by specific beekeeping practices (not necessarily as primary outcome): - Recorded in-hive mortality after specific practice
	Out	Not acceptable method for assessing background mortality: Measure mortality in front of the hive (e.g. dead bee trap, linen sheets, etc.) or only inside the hive (unless this is done after a specific beekeeping practice)
Landscape	**In**	All possible locations
	Out	/

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286 **Table 4. Criteria for selecting studies for questions 2 and 5 (bumble bees - *Bombus spp*.)**

Study design	**In**	Field studies [Performed in open settings where the variables naturally occur with minimal direct influence of human. In field studies, the bees are free-flying, exposed to any stressor due to their natural activity. Unavoidable intervention by the beekeepers (for managed bees) may take place]
	Out	Lab studies Semi-field studies Colony-feeding studies (even if field design) Modelling/in-silico studies
Population	**In**	Bumble bee, species occurring in EU
	Out	Rest of bees, other animals, etc.
Exposure	**In**	Natural/Normal [No excessive exposure to anthropogenic effects, which may cause elevated mortality. Note that bees may still be exposed to anthropogenic effects e.g. to chemicals that are normally used in agricultural landscapes. As long as the levels of these stressors are considered as comparable with the usual background level, the study is considered as eligible]
	Out	Specific exposure to a stressor outside of background range [When an anthropogenic stressor is considerably higher (even temporarily) than the usual background level, the study or that experiment is considered as non-eligible. For example, if a study is specifically done for assessing the effects of an exposure to a chemical, the treatment part should be left out]
Outcome	**In**	Information on background mortality (not necessarily as primary outcome): Acceptable methods for assessing background mortality: - Measure of the lifespan (longevity) of the bee. - Direct estimation of forager mortality via tagging of individual bees. - Mortality is assessed indirectly by monitoring the population in the hive together with the brood production

		(unlikely to provide suitable information due to practical limitations). Information on mortality caused by specific beekeeping practices (not necessarily as primary outcome): - Recorded in-hive mortality after specific practice
	Out	Not acceptable method for assessing background mortality: Measure mortality in front of the hive/nest (e.g. dead bee trap, linen sheets, etc.) or only inside the hive (unless this is done after a specific beekeeping practice)
Landscape	**In**	All possible locations
	Out	/

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288 **Table 5. Criteria for selecting studies for questions 3a and 3b (solitary bees)**

Study design	**In**	- Field studies [artificial nesting units placed for experimental reasons]; - Population monitoring [population abundance is estimated in a certain area without the aid of artificial nesting units] [In both cases studies performed in open settings where the variables naturally occur with minimal direct influence of human. The bees are free-flying, exposed to any stressor due to their natural activity]
	Out	Lab studies Semi-field studies Feeding studies (even if field design) Modelling/in-silico studies
Population	**In**	Solitary bee, species occurring in EU
	Out	Rest of bees, other animals, etc.
Exposure	**In**	Natural/Normal [No excessive exposure to anthropogenic effects, which may cause elevated mortality. Note that bees may still be exposed to anthropogenic effects e.g. to chemicals that are normally used in agricultural landscapes. As long as the levels of these stressors are considered as comparable with the usual background level, the study is considered as eligible]
	Out	Specific exposure to a stressor outside of background range [When an anthropogenic stressor is considerably higher (even temporarily) than the usual background level, the study or that experiment is considered as non-eligible. For example, if a study is specifically done for assessing the effects of an exposure to a chemical, the treatment part should be left out]
Outcome	**In**	Information in background mortality (not necessarily as primary outcome): - Mortality is assessed indirectly by monitoring the population

		- Measure of the lifetime (longevity) of the bee - Estimate of winter mortality by measuring emergence failure.
	Out	Measure mortality only in cave/nest Measure only abandoned cave/nest
Landscape	**In**	All possible locations
	Out	/

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290 **Table 6. Criteria for study selection related to report characteristics and relevant the three bee species**

Time	**In**	No time limits
	Out	/
Language	**In**	European languages (with abstract in English).
	Out	Rest of languages
Publication type	**In**	Primary research studies (i.e. studies generating new data). Reviews will be used as sources of further references and to assess the appropriateness of the search strategy applied. Conference abstracts or posters if they contain primary data. PhD theses and dissertations
	Out	Letters to editor Expert opinions Editorials

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292 ### 3.1.2. Extensive literature searches

293 The bibliographic databases listed in Table 7 will be searched in order to identify relevant
294 studies. The databases have been identified in line with the defined scope of the review.

295 **Table 7. Bibliographic databases searched for relevant studies**

Source of information	Platform
BIOSIS Citation Index (1926-present)	Web of Science
CAB Abstracts (1920-present)	Web of Science
Scopus (inception-present)	Scopus
Zoological Record (1864-present)	Web of Science
Web of Science Core Collection • Science Citation Index Expanded (1975-present) • Conference Proceedings Citation Index- Science (1990-present) • Emerging Sources Citation Index (2005-present)	Web of Science
DART-Europe E-theses Portal	DART Europe
EBSCO Open Dissertations	EBSCOhost

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297 The search strings that will be used are available in Appendix A. They are structured to include
298 the combination of the population concept (honeybees, bumble bees and solitary bees) and
299 the outcome concept (background mortality and beekeeping mortality). A wide range of
300 search terms are used to cover possible synonyms, related terms, lay and scientific
301 terminology, etc. Several sources have been used to select the search terms: studies included

in the previous EFSA guidance (EFSA, 2013); search strings used for the searches in the ApisRAM project (OC/EFSA/SCER/2016/03); thesaurus such as, Biosis Citation Index, CAB Thesaurus and Zoological Record Thesaurus; the European Red List of Bees (Nieto et al. 2014) has been consulted in order to gather all the bee species of interest. The terms have been combined using the appropriate Boolean and proximity operators.

According to Nieto et al. (2014) there are more than 1500 species of solitary bees in Europe. After testing some search strings including the species name (scientific and lay names), it was decided to take a practical approach using only the family and subfamily terms. This approach was complemented with a search string that combines terms for bees and terms to refer to European countries and regions.

Language of the original studies will be limited to European languages for bibliographic databases; the retrieval of PHD theses will be limited to English. No time limits will be applied to the searches.

The output of the searches i.e. records retrieved from bibliographic databases will be exported into one Endnote library (Clarivate Analytics). Duplicate references will be removed by a combination of automatic and manual detection of duplicates.

If reviews are retrieved, the reference list of included studies will be checked in order to identify potential studies not retrieved in other sources.

The final search processes and strategies will be documented and reported in the technical report, i.e. the date of the search, sources of information, search string for each bibliographic database and additional sources, and the number of records before and after de-duplication. Should modifications in the search strings be considered after the publication of the protocol, they will be reported.

3.1.3. Data submitted to EFSA via application dossiers

In principle, data submitted to EFSA through application dossiers could be screened against the eligibility criteria illustrated above and, if relevant, included in the assessments. The selection process could be the same as for studies retrieved from the open literature (see section 3.1.5.).

In practice, the large majority of studies included in application dossiers do not provide useful information against the eligibility criteria, as the limited number of available field studies does not usually provide indication about the endpoints identified under section 2.1.3. However, when assessing the risk posed by three neonicotinoids substances (i.e. imidacloprid, clothianidin, and thiamethoxam) to bees (EFSA, 2018), EFSA put together a large database of studies characterised by a very wide set of typologies and with very different scopes, including literature data, data submitted via open call (EFSA, 2015) and data included in application dossiers. Due to the diverse nature of this database, some relevant information is potentially available, hence this database will be screened as well.

3.1.4. Study selection process

All records retrieved via the literature searches and those belonging to the neonicotinoid database (EFSA 2018) will be screened against the eligibility criteria defined above.

For the literature retrieved records, the study selection process will be done in two steps:

1. Step 1: titles and abstracts screening, to exclude obviously irrelevant records. All other apparently relevant or of unclear relevance records will be moved to the following step;

2. Step 2: full-text screening, to select records for inclusion/exclusion and, if possible at this stage, cluster the included studies by relevance to the assessment questions (see table 1). It is foreseen that in principle a record can be relevant to more than one question.

Each record will be screened by two independent reviewers (EFSA staff), to minimise the risk of error using DistillerSR® (Evidence Partners, Ottawa, Canada). Between-reviewer conflicts not solvable via discussion will be discussed at among all reviewers.

For the neonicotinoids database, as the reviewers (EFSA staff) are already familiar with the studies, the selection process will be condensed in a single screening step, performed in Excel. Records deemed relevant after the screening phase will be uploaded into DistillerSR® for the following phases of the process (i.e. appraisal and data extraction).

During the study selection process, studies published in multiple publications will be identified and duplicates removed.

Eligibility criteria will be pilot tested on a subset of records and refined if prone to misinterpretation. The results of the different phases of the record selection process will be reported in a flowchart as recommended in the PRISMA statement on preferred reporting items for systematic reviews and meta-analyses (Moher et al., 2009).

Records with abstract in English and full-text in another European language that will seem relevant based on the abstract will be translated or screened by knowledgeable EFSA staff.

3.1.5. Data extraction from relevant studies

During this step of the assessment process, the records selected for inclusion will be further screened to 'unpack' them in individual study units (as a record can contain multiple studies) and, if needed, cluster these units by relevance to the assessment questions. Then from each study unit data will be extracted in light of the foreseen evidence synthesis process. Different publications reporting on the same study possibly overlooked in the previous step of the process will be identified at this stage.

Data extraction will be done using predefined forms that will be aligned as much as possible with the data model developed for the primary data collection via the ApisRAM project. The data related to parameters providing information on bee mortality, such as ratio of bees going for foraging with the bees coming back after foraging, number of animals dead in a hive, or other ways of measuring mortality, together with information on landscape, based on for instance Corine database, as well as climatic information considering JRC climate data will be collected for each paper, in relation to location of the study conducted and other parameters that could influence the mortality.

Instructions for extracting data will be developed. The data extraction forms will be created in DistillerSR® and/or Excel, and possibly pilot tested on a subset of studies. The piloting will also be used to identify sources of heterogeneity across studies. The forms and instructions will be refined if needed.

3.1.6. Survey sent to beekeepers (assessment question 4)

For honey bee mortality due to specific beekeeping practice, it is expected that the information available in the scientific literature will not provide enough insight to draw any robust conclusion. Hence, a second source of information has been included in the assessment planning, which consists in a targeted survey addressed to beekeepers.

Beekeeper association of at least 10 European countries will be contacted to provide contact details of at least 10 professional/industrial and 10 amateur bee keepers willing to participate to the survey. The countries should cover all three European regulatory zones (Northern-, Central-, Southern- Europe).

In case the number of responding countries is less than 10, the total number of 100 professional/industrial and 100 amateur beekeepers should still be reached, also all 3 European regulatory zones should be covered by either choosing another country or by increasing the numbers of contact bee keepers per country.

The survey will be sent individually to the nominated beekeepers. Reminders will be sent until a minimal response rate of 50% is reached for professional and amateur bee keepers each.

Detailed description of the way of contacting and managing the beekeepers

In order to reach the goal to get responses from about one hundred or more beekeepers representing amateurs and professionals from different EU regions, the following steps will be performed:

- Via the Pesticide Steering Network, EFSA will contact the competent national authorities asking them to identify active beekeeping associations and select one or two associations according to the following considerations:
    - sufficient members from different regions of the country
    - members include hobbies (amateur) and more professional beekeepers
    - the association has some active information exchange channels in place that is used to contact their members and receive feedbacks from them (e.g. newsletters, regular meetings etc).
- From the list of candidate associations, EFSA will select at least 10 associations from at least 10 different countries that geographically represents the territory of the EU and covers the three regulatory zones. Moreover, the distribution of different honey bee subspecies within the EU will be considered. If a balanced selection is not possible with the received list of candidate associations, EFSA may identify themselves additional beekeeper associations and add them to the list.
- EFSA will identify internal staff who speak the languages of the selected beekeeper associations. These EFSA employees will contact (by phone) the chief officer(s) of the respective beekeeper association(s) and explain them the context and the aim of the survey. The chief officer(s) (or other suitable officers, board of the association) will be invited to identify at least 20 beekeepers from their members, in accordance to the following considerations:
    - It is expected that the beekeepers are willing to participate in the survey
    - The beekeepers are known as a responsible people, therefore it is likely that the beekeeper will answer to the survey's questions in a reasonable manner

- The identified people will equally represent the amateur and professional beekeepers and will geographically represent the service environment of the association
- The beekeepers agree that their email address will be shared by EFSA for this purpose

- Pending on the feedback received (i.e. number of potential respondents, geographical representation etc.), EFSA will create the final list of participants with their email addresses (provided by the associations)
- The related associations (relevant officer of the association) will be asked to inform the selected beekeepers that the survey of EFSA will arrive to their email address within a couple of days and the associations will be asked to encourage the beekeepers for the active participation
- EFSA will send the survey (internet link) to the whole distribution list of beekeepers with a short introduction and description of the purpose of the survey. Technical details and the deadline will also be indicated. The instructions and the survey itself will be in the language used by the association (prepared by the appointed EFSA staff).
- The form of the survey will be the 'EUsurvey' (European Commission's ISA² programme) and it will be open for two weeks.
- EFSA will follow the progress of the completion of the survey and if needed, EFSA will send reminders for the non-respondent beekeepers after a week and 3 days before the close of the survey.
- If necessary (low number of responds received by the deadline), EFSA may keep the survey open for an additional week and inform about it the non-respondent beekeepers.
- In case of need, EFSA call for support of the competent national authorities (i.e. relevant members of the Pesticide Steering Network) for any steps that involve communication with the associations and the beekeepers.

Content and expectations from the survey

Relevant beekeeping practices have been identified via some preliminary analysis of previous EFSA output (e.g. EFSA AHAW Panel, 2016) or other recent literature (e.g. Underwood et al., 2019; Sperandio et al., 2019). However, the main input in the compilation of the final list came from the involvement of EFSA staff having beekeeping experience.

This list (below) includes 20 different practices:

1. Opening of the hive
2. Smoking the bees
3. Removal/introduction of frames
4. Hive displacement/relocation
5. Introduction of new worker bees/merge colonies
6. Introduction of a new queen/requeening
7. Introduction of honey supers (including queen excluder)
8. Removal of honey supers and brushing off bees (harvesting of honey)
9. Shook/artificial swarms
10. Queen confinement
11. Introduction of feeder
12. Provisioning of supplementary feeding/insulate/winterize
13. Harvesting of other bee products (e.g. collection of pollen, wax, propolis, royal jelly)
14. Chemical treatments (i.e. control of varroa, AFB, EFB, Nosema, etc)

15. Displacement of mesh board
16. Trapping of pests (i.e. use of in-hive traps and bottom-board traps)
17. Drone brood removal
18. Queen rearing
19. Activities related to the monitoring/control of pests (i.e. conduct powdered sugar roll or similar techniques)
20. Closing the hive

Each of the survey recipient will be asked to flag the practices that they actually put in place. Each recipient applying a method should indicate the average annual frequency that they perform the practice on a single hive. It is assumed that each practice is applied by at least 10% of the beekeepers hence it would result in a minimum of 5 answers per bee keeping category. If recipient perform an activity what is not in the list above, he/she can add this activity to the list.

In addition, for each activity what they perform, the recipients should indicate how frequently they observed more than 100 dead bees following the application of a specific practice. In occasions when more than 100 dead bees could be observed, the recipients should also provide an estimation of the mean number of the observed dead bees.

The trigger of 100 dead bees had been chosen for multiple reasons:

- Even in a rather small colony of 10000 adult bees, 100 individuals represent 1% of the colony, i.e. a mortality well below the range (5.26-20.8%) of daily honey bee forager mortality rates reported in EFSA (2013). This would indicate that, the impact of the beekeeping practice on the overall mortality of the colony is minimal.
- Estimating numbers below 100 individuals might be complicated as mortality of few bees might even go unnoticed. On the contrary, situations where the number of dead bees is greater than 100 individuals are likely to trigger the attention of the beekeeper, which could then provide more reliable information.

3.2. Methods for appraising evidence

In this step of the process the Risk of internal and external Bias (RoB) and imprecision of each included study will be assessed, separately

In a descriptive study, a biased study is one that does not give a true representation of the situation we want to describe.

In particular, internal bias refers to any error in the conduct of the study that results in a conclusion which is different from the truth we are interested in. The method for measuring background mortality not being reliable/accurate is an example of source of internal bias in the studies relevant to this assessment.

External bias affects the extent to which the study results are generalisable to the assessment question, e.g. when the study settings are not being representative of the reference population/conditions/landscape settings

The third aspect that will be assessed concern the possible imprecision of the studies included in the assessment, which is related to random error and indicates the ability of a study to provide similar results when repeated under the same conditions. These aspects are mainly related to the sample size of the studies, which may not be large enough for providing a precise estimate of mortality.

Internal and the external validity (or risk of internal and external bias) and imprecision will be appraised for each individual study using the critical appraisal tools (CAT) illustrated in the

following tables. The 4-level rating instructions were inspired by the OHAT/NTP tool for RoB assessment (add ref). The tool will be translated in the review management software DistillerSR® to allow web-based appraisal of the studies.

Each study will be appraised by two independent reviewers from the EFSA WG working on the revision of the EFSA Guidance Document (i.e. including EFSA staff and external experts). Possible discrepancies not solvable via discussion between the two reviewers will be discussed by the whole WG. If upon further discussion the WG cannot reach an agreement on a rating, the more conservative judgment (the highest RoB/imprecision) will be selected.

The CAT will be pilot tested by two reviewers. Feedbacks from this testing phase will be used for further refining this process. Hence, the CAT finally used for the assessment may present some modifications compared to the one reported here.

536 **Table 8. Critical appraisal tool for the included studies for all outcomes (internal bias)**

Domain	Risk of internal bias Question	Rating	Rationale	Relevance by assessment question and related outcomes			
				Beekeeping-practice specific mortality (questions 4 and 5)	HB overwintering (question 1b)	SB overwintering (question 3b)	Any other question and related outcomes active period (questions 1a, 2, 3a)
Study conditions	1. Are weather conditions suitable for ensuring proper foraging activities?	Definitely low RoB	Weather conditions are known, and they are representing reasonable conditions for ensuring good foraging activities throughout the study period (mostly sunny and warm during all the study period).	X (depending on the practice)	X (Temperature only)	X (Temperature only)	X
		Probably low RoB	Weather conditions are at least broadly known, and they are such that, for more than half of the study period, some foraging activity could be carried out.				
		Probably high RoB/NR	Weather conditions are not reported. OR It can be inferred that they are not suitable for foraging				
		Definitively high RoB	There is clear evidence that weather conditions were characterised by prevalence of cold and/or rainy/cloudy days. Under these conditions foraging is impaired, and mortality is likely affected too.				
Test organisms	2. Are the test organisms free from unrealistic/unusual	Definitely low RoB	The tested organisms are known to be healthy (or with realistic disease prevalence) and immune from previous stress.	X	X	X	X

Domain	Risk of internal internal bias Question	Rating	Rationale	Relevance by assessment question and related outcomes			
				Beekeeping-practice specific mortality (questions 4 and 5)	HB overwintering (question 1b)	SB overwintering (question 3b)	Any other question and related outcomes active period (questions 1a, 2, 3a)
	stressors (e.g. not typical disease)?	Probably low RoB	No specific information is reported but the rearing methodology raises no particular concern for disease or unrealistic stress.				
		Probably high RoB/NR	Some indications are available suggesting that the tested bees might have been unusually stressed before or during the experiment or whether they might be affected by diseases with an unrealistic prevalence. OR No suitable information for assessing the health or the stress status of the bees is available.				
		Definitively high RoB	It is known that the tested bees were unrealistically stressed before or during the experiment AND/OR Bees were known to be affected by some disease with an unrealistic prevalence.				
	3. Is the food stock (honey and/or provision of sugar syrup) at the beginning of winter appropriate?	Definitely low RoB	Honey availability pre-winter considered as sufficient.	N/R	X	N/R	N/R
		Probably low RoB	Honey availability pre-winter is not reported, but extra food (e.g. sugar syrup) is provided by the beekeeper so that this is unlikely to cause an issue in the measured outcome.				

Domain	Risk of internal internal bias Question	Rating	Rationale	Relevance by assessment question and related outcomes			
				Beekeeping-practice specific mortality (questions 4 and 5)	HB overwintering (question 1b)	SB overwintering (question 3b)	Any other question and related outcomes active period (questions 1a, 2, 3a)
		Probably high RoB/NR	Honey availability and provision of extra food (e.g. sugar syrup) from the beekeeper is not reported.				
		Definitively high RoB	Honey availability is documented and scarce. The beekeeper did not provide any extra food (e.g. sugar syrup). This is likely to strongly bias the outcome compared to good beekeeping practices.				
Outcome	4. Is the methodology for measuring the relevant outcome (endpoint) reliable?	Definitely low RoB	The method for measuring the outcome is well detailed and it is considered suitable to get a reliable estimation of the outcome in the conditions of the study. Ideally, an estimation of the accuracy of the method is given and it is satisfactory. The measuring methodology is unlikely to introduce behavioural changes in bees that may bias the outcome.	X	X	X	X

Domain	Risk of internal internal bias Question	Rating	Rationale	Relevance by assessment question and related outcomes			
				Beekeeping-practice specific mortality (questions 4 and 5)	HB overwintering (question 1b)	SB overwintering (question 3b)	Any other question and related outcomes active period (questions 1a, 2, 3a)
		Probably low RoB	The method for measuring the outcome is only broadly described but raise no concern about the reliability of the measurement. OR The method for measuring the outcome presents only minor issues in terms of reliability. OR The method for measuring the outcome has potential for altering the bee behaviour, but the impact on the final outcome is considered low.				
		Probably high RoB/NR	The method for measuring the outcome is not sufficiently described. OR No estimation about the accuracy of the method is given, and there are valid concerns that the method may not provide an reliable estimation of the outcome. OR The method has the potential for inducing some behavioural changes with potential repercussion on the final outcome measurement.				

Domain	Risk of internal internal bias Question	Rating	Rationale	Relevance by assessment question and related outcomes			
				Beekeeping-practice specific mortality (questions 4 and 5)	HB overwintering (question 1b)	SB overwintering (question 3b)	Any other question and related outcomes active period (questions 1a, 2, 3a)
		Definitively high RoB	The methodology for measuring the outcome is known to be poorly reliable. OR The method is likely to induce serious behavioural changes with repercussion on the final outcome measurement.				
	5. Are the sampling dates well-chosen for estimating winter mortality?	Definitely low RoB	Measurements are known to be performed right before closing the hive before winter and immediately after re-opening it after winter dormancy.	N/R	X	X	N/R
		Probably low RoB	It can be reasonably inferred that the measurements are performed shortly (<2 weeks) before and after winter and no significant foraging activity nor brood rearing had happened in the measurement period.				
		Probably high RoB/NR	The dates of the measurements are not known and/or cannot be related with the period of inactivity of the hive.				
		Definitively high RoB	The measurement were performed significantly before closing the hive/start of hibernation (>2-3 weeks), and significantly after (>2-3 weeks) re-start of foraging activities.				

Domain	Risk of internal internal bias Question	Rating	Rationale	Relevance by assessment question and related outcomes			
				Beekeeping-practice specific mortality (questions 4 and 5)	HB overwintering (question 1b)	SB overwintering (question 3b)	Any other question and related outcomes active period (questions 1a, 2, 3a)
Data	6. Are the presented data elaboration/statistical analysis appropriate and consistent with the initial proposal of the study?	Definitely low RoB	There is clear evidence that the statistical analysis was appropriate OR The elaboration was wrong/inappropriate, but data are available with sufficient level of disaggregation (e.g. raw data, detailed table or plots) that allows performing a more appropriate analysis*	X	X	X	X
		Probably low RoB	Data elaboration is available, although not all passages are clear from the reporting of the methodology. However, the degree of uncertainty is not likely to impair the reliability of the outcome analysis.				
		Probably high RoB/NR	Data elaboration is obscure and there are severe doubts that the presented outcome was estimated correctly. Underlying data not available.				
		Definitively high RoB	From the reporting in the methodology section it is clear that major errors were performed and/or inappropriate elaboration methods have been used for estimating the outcome. Underlying data not available.				

538 * In this case, the outcome that will be extracted is the one resulting from the re-analysis of the data. Hence, while formally the study itself has issues in
539 terms of internal validity, the final outcome used for the present assessment will not present the same concern.

540 **Table 9. Critical appraisal tool for the included studies for all outcomes (external bias)**

Domain	Risk of external bias question	Rating	Rationale	Relevance by assessment question and related outcomes			
				Beekeeping-practice specific mortality (questions 4 and 5)	HB overwintering (question 1b)	SB overwintering (question 3b)	Any other question and related outcomes active period (questions 1a, 2, 3a)
Study conditions	1. Is the study location representative of any EU biogeographic region?	Definitely low RoB	It is known that the study had been conducted in the EU, therefore the relevant outcome is not affected by the any bias compared to the target assessment.	X (depending on the practice)	X	X	X
		Probably low RoB	It is known that the study had been conducted outside of the EU, but the study area is located in a geographical area which presents comparable bio-climatic conditions to at least one of the EU biogeographic regions (see section 2.1.2).				
		Probably high RoB/NR	It is known that the study had been conducted outside of the EU, but it is not so clear that the study area is located in a geographical area which presents comparable bio-climatic conditions to at least one of the EU biogeographic regions. OR The study area is not known and cannot be reliably inferred.				

		Definitively high RoB	The study is carried out in an area which presents bio-climatic conditions different to any EU biogeographic region (see section 2.1.2).				
	2. Is the study setting representative of an EU agricultural landscape?	Definitely low RoB	It is known that the study had been conducted in a typical European agricultural setting, including primarily crops and orchard grown in EU. The relevant outcome is not affected by the any bias compared to the target assessment.	X (depending on the practice)	N/R	N/R	X
		Probably low RoB	The study has been carried out in a mixed landscape, comprising pristine habitats and/or urban settlements together with agricultural lands. It is expected that the bias would only be minimal.				
		Probably high RoB/NR	The landscape of the study area is not known and cannot be reliably inferred.				
		Definitively high RoB	The study is carried out either in pristine natural habitats (e.g. forest) or in fully urban/industrial context. In both cases food availability (and therefore the foraging area) is likely to be strongly impacted. Predation and orientation loss are also likely to be greatly influenced. OR The study is carried out in an agricultural setting dominated by crops not grown in the EU.				
	3. Are all the relevant beekeeping/bee management	Definitely low RoB	Beekeeping practices are well reported and in accordance with good beekeeping principles.	X	X	N/R	X (mainly managed bees)

	practices realistic? Are they performed according to good beekeeping practices?	Probably low RoB	Beekeeping practices are not detailed but only briefly and broadly described. No particular deviations noted from realistic and appropriate beekeeping practices are noted.				
		Probably high RoB/NR	Beekeeping practices are not detailed but only briefly and broadly described. Potential misconduct of the beekeeper is noted. OR Beekeeping practices not reported at all.				
		Definitively high RoB	Beekeeping practices are reported, and clear misconduct of the beekeeper is noted.				
Outcome	4. How confident are we that the measured outcome can be used for reliably estimating background mortality rate?	Definitely low RoB	The measured outcome can be directly related to the background mortality rate: a reliable estimation of the outcome gives immediately a reliable estimation of background mortality rate.	X	X	X	X
		Probably low RoB	The measured outcome is logically related with background mortality rate, but there are some uncertainties in extrapolating from one to the other. [For example, honeybee worker longevity can be used for estimating background mortality uniquely under an assumption of more or less constant colony strength.]				
		Probably high RoB/NR	The measured outcome is logically related with background mortality rate, but there are major uncertainties in extrapolating from one to the other. [For example, span of the foraging life stage requires the same assumptions listed for honeybee worker longevity, plus that a negligible mortality is assumed during the in-hive phase				

			and that the time needed for foraging recruitment is constant]				
		Definitively high RoB	The measured outcome is unlikely to offer a reliable picture of the background mortality rate. [For example, measurements of colony strengths performed with interval of several weeks do not offer a reliable estimate of the mortality]				

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543 **Table 10. Critical appraisal tool for the included studies for all outcomes (imprecision)**

Domain	Risk of internal internal bias Question	Rating	Rationale	Relevance by assessment question and related outcomes			
				Beekeeping-practice specific mortality (questions 4 and 5)	HB overwintering (question 1b)	SB overwintering (question 3b)	Any other question and related outcomes active period (questions 1a, 2, 3a)
Outcome	1. Is the sample size appropriate?	Very high precision	The sample size is large enough to achieve a very high level of precision on the mortality estimate. [For example, it is estimated that, considering a hive with >10000 bees, ideally >6000 bees should be monitored to get an estimate of the mortality rate with a precision of ±1% and 95% confidence.]	X	X	X	X

Domain	Risk of internal internal bias Question	Rating	Rationale	Relevance by assessment question and related outcomes			
				Beekeeping-practice specific mortality (questions 4 and 5)	HB overwintering (question 1b)	SB overwintering (question 3b)	Any other question and related outcomes active period (questions 1a, 2, 3a)
		High precision	The sample size is large enough to achieve a rather high level of precision on the mortality estimate. [For example, it is estimated that, considering a hive with >10000 bees, ideally >680 bees should be monitored to get an estimate of the mortality rate with a precision of ±3% and 95% confidence.]				
		Low precision	The sample size is large enough to give some ideas about the actual mortality rate, although any further use of the estimate must account for the rather low precision it is able to offer (e.g. explicit consideration of the error should be made). [For example, it is estimated that, considering a hive with >10000 bees, ideally >60 bees should be monitored to get an estimate of the mortality rate with a precision of ±10% and 95% confidence.]				

Domain	Risk of internal internal bias Question	Rating	Rationale	Relevance by assessment question and related outcomes			
				Beekeeping-practice specific mortality (questions 4 and 5)	HB overwintering (question 1b)	SB overwintering (question 3b)	Any other question and related outcomes active period (questions 1a, 2, 3a)
		Very low precision	The sample size is so small that the study cannot offer a reliable picture of the measured outcome. In this situation, the effect of stochastic processes can be disproportionate with respect to their actual prevalence for the whole population. [For example, it is estimated that, considering a hive with >10000 bees, monitoring of less than 60 bees will provide a mortality rate with errors wider than ±10% (95% confidence)]				

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3.2.1. Summarising the internal validity, external validity and precision of each individual study

For two out of the three categories identified above (internal validity, external validity), key questions are identified. Key and non-key questions will be combined into a single scoring method, classifying each endpoint from each study into a different tier reflecting the Risk of Bias.

Table 11. Summary of key and non-key questions for the assessment of the internal validity

Appraisal questions	**Key (Y/N)**
1. Are weather conditions suitable for ensuring proper foraging activities?	Y
2. Are the test organisms free from unrealistic/unusual stressors (e.g. not typical disease)?	N
3. Is the food stock (honey and/or provision of sugar syrup) at the beginning of winter appropriate?	Y
4. Are the presented data elaboration/statistical analysis appropriate and consistent with the initial proposal of the study?	Y
5. Is the methodology for measuring the relevant outcome (endpoint) reliable?	N
6. Are the presented data elaboration/statistical analysis appropriate and consistent with the initial proposal of the study?	Y

Table 12. Summary of key and non-key questions for the assessment of the external validity

Appraisal questions	**Key (Y/N)**
1. Is the study location representative of any EU biogeographic region?	Y
2. Is the study setting representative of an EU agricultural landscape?	Y
3. Are all the relevant beekeeping/bee management practices realistic? Are they performed according to good beekeeping practices?	Y (only for assessment questions 4 and 5)
4. How confident are we that the measured outcome can be used for reliably estimating background mortality rate?	N

Table 13. Algorithm to combine the answers to the appraisal questions and allocate studies to tiers of RoB (both internal and external validity)

Algorithm	**Tier**
From OHAT/NTP: *– "definitely low" or "probably low" risk of bias for key items* *AND* *– "definitely low" or "probably low" risk of bias for most other applicable criteria*	1 (low RoB)

study does not meet criteria for "low" or "high"	2 (intermediate RoB)
– "definitely high" or "probably high" risk of bias for key items AND – "definitely high" or "probably high" risk of bias for most other applicable criteria	3 (high RoB)

For the quantification of precision, as only one question was identified, there is no need to further summarising. However, in order to make comparable scaled for the three dimensions, the 4-grades classification used for the question related to the sample size, will be reduced to a three-levels tier by merging the two highest grades ("Very high precision" and "High precision") into the Tier1 class.

The results of critical appraisal will be summarised by using appropriate techniques, using for example heatmap tables as the one reported below.

Refid metadata	Endpoint(s)	Results	Internal validity	External Validity	Precision
			Tier 1	Tier 2	Tier 1
			Tier 3	Tier 3	Tier 2
			Tier 1	Tier 1	Tier 3

4. Methods for synthesising/integrating evidence and analysing uncertainty

4.1. Evidence from literature

Considering the nature of the outcome variable of interest, being the number of dead bees in relation to the total number of bees in the colony, also other endpoint such as longevity, a generalized linear mixed model could be used to estimate background mortality accounting for other factors, such as landscape, environmental conditions, etc. The final choice of the method to be used will depend on the granularity of the information retrieve and type of data that is retrieved.

The external and internal validity tiers will be used to construct a matrix with the number of studies retrieved in each of the nine cells, to conduct subgroup analysis of studies in specific tier combinations to explore the impact on the final estimation of the parameter of interest.

The results from different subgroups considering internal and external validity provides a structural way to assess uncertainty across the different tier combinations. In the case that subgroup analysis might lead to different conclusions, an expert knowledge elicitation might

be considered to get an overall conclusion to integrate uncertainties included in the results obtained.

Pending on the amount, the quality, and the diversity of the information that will be retrieved, the possibility exists that no meaningful synthesis will be possible. In this case, the data will be presented as such, without any further elaboration.

4.2. Evidence from survey sent to beekeepers

Questions on the number of bee hives and locations will be used to verify the stratification among professional/industrial and amateur bee keepers, as well as the distribution among regulatory zones.

Per specific bee keeping practice, the frequency of application and irregular events (more than 100 dead bees) will be used to calculate the rate of irregular events.

From the sample, the average rate of irregular events and its confidence interval will be calculated per bee keeping practice (if the response rate allows, also further stratification by climatic zone), as well as the average number of dead bees per irregular event.

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Glossary [and/or] Abbreviations

Glossary: an alphabetical list of words relating to a specific subject, text, or dialect, with explanations; a brief dictionary.

Abbreviation: a shortened form of a word or phrase (such as Mr., Prof.). It also includes acronyms (a group of initial letters used as an abbreviation for a name or expression, each letter being pronounced separately – such as DVD, FDA – or as a single word – such as EFSA, NATO).

XXX	Dsadsadsadsa
YYY	Sdsdsadsad
ZZZ	Fdsfsafasdf

Appendix A – Search strings

649

650 BIOSIS

Set	Query
# 7	#6 AND LANGUAGE: (English OR Albanian OR Bulgarian OR Catalan OR Croatian OR Czech OR Danish OR Dutch OR Estonian OR Finnish OR French OR Gaelic OR German OR Greek OR Hungarian OR Icelandic OR Irish OR Italian OR Latvian OR Lithuanian OR Macedonian OR Netherlandish OR Norwegian OR Polish OR Portuguese OR Provencal OR Romanian OR Serbian OR Serbo-Croatian OR Slovak OR Slovenian OR Spanish OR Swedish OR Unspecified OR Welsh) Indexes=BCI Timespan=All years
# 6	#5 AND #4 Indexes=BCI Timespan=All years
# 5	TS=("flight span" OR flightspan OR "life cycle" OR "life expectancy" OR "life history" OR "life span*" OR "life table*" OR "life time" OR lifespan* OR lifetime* OR longevit* OR mortalit* OR survival OR survivorship OR ((colony OR colonies) NEAR/3 (strength OR loss*)) OR ((death OR loss* OR declin*) NEAR/3 (rate* OR population*)) OR (emergence NEAR/3 (fail* OR success*)) OR ((overwinter* OR hiberna*) AND (contract* OR declin* OR loss* OR health OR population*)) OR ((beekeep* NEAR/3 (amateur* OR competenc* OR education OR experience* OR knowledge OR management OR practice* OR professional* OR role OR roles)) AND (health OR stress*))) Indexes=BCI Timespan=All years
# 4	#3 OR #2 OR #1 Indexes=BCI Timespan=All years
# 3	TS=((solitary NEAR/3 (bee OR bees)) OR Afranthidium OR Aglaoapis OR Amegilla OR Ammobates OR Ammobatoides OR Ancyla OR Andrena OR ANDRENIDAE OR ANDRENINAE OR Anthidiellum OR Anthidium OR Anthophora OR APIDAE OR APINAE or Biastes OR Camptopoeum OR Ceratina OR Ceylalictus OR Chelostoma OR Chiasmognathus OR Clavipanurgus OR Coelioxys OR Colletes OR COLLETIDAE OR COLLETINAE OR Cubitalia OR Dasypoda OR DASYPODAINAE OR Dioxys OR Dufourea OR Ensliniana OR Eoanthidium OR Epeoloides OR Epeolus OR Eucera OR Flavipanurgus OR Habropoda OR Haetosmia OR HALICTIDAE OR HALICTINAE OR Halictus OR Heriades OR Hofferia OR Hoplitis OR HYLAENIAE OR Hylaeus OR Icteranthidium OR Lasioglossum OR Lithurgus OR Macropis OR Megachile OR MEGACHILIDAE OR MEGACHILINAE OR Melecta OR Melitta OR MELITTIDAE OR MELITTINAE OR Melitturga OR Metadioxys OR (Nomada AND (bee OR bees)) OR NOMADINAE OR NOMIINAE OR Nomiapis OR NOMIOIDINAE OR Nomioides OR Osmia OR Panurginus OR Panurgus OR Paradioxys OR Parammobatodes OR Pasites OR PANURGINAE OR Protosmia OR Pseudoanthidium OR Rhodanthidium OR RHOPHITINAE OR Rhophitoides OR Rophites OR Schmiedeknechtia OR Simpanurgus OR Sphecodes OR Stelis OR Stenoheriades OR Systropha OR Tarsalia OR Tetralonia OR Tetraloniella OR Thrincohalictus OR Thyreus OR Trachusa OR Triepeolus OR Xylocopa OR XYLOCOPINAE) Indexes=BCI Timespan=All years
# 2	TS=("managed bee" OR "managed bees" OR "Apis mellifera" OR "Apis mellifica" OR "a mellifera" OR "a mellifica" OR Honeybee* OR "honey bee*" OR Bombus OR Bumblebee* OR "Bumble bee*" OR "B. alpinus " OR "B. argillaceus " OR "B. armeniacus " OR "B. balteatus " OR "B. barbutellus " OR "B. bohemicus " OR "B. brodmannicus " OR "B. campestris" OR "B. cingulatus " OR "B. confusus " OR "B. consobrinus" OR "B. cryptarum" OR "B. cullumanus " OR "B. deuteronymus" OR "B. distinguendus" OR "B. flavidus " OR "B. fragrans " OR "B. gerstaeckeri " OR "B. glacialis " OR "B. haematurus " OR "B. hortorum " OR "B. humilis " OR "B. hyperboreus " OR "B. hypnorum " OR "B. inexspectatus " OR "B.

	jonellus" OR "B. laesus" OR "B. lapidarius" OR "B. lapponicus" OR "B. lucorum" OR "B. magnus" OR "B. mendax" OR "B. mesomelas" OR "B. mlokosievitzii" OR "B. mocsaryi" OR "B. modestus" OR "B. monticola" OR "B. mucidus" OR "B. muscorum" OR "B. niveatus" OR "B. norvegicus" OR "B. pascuorum" OR "B. patagiatus" OR "B. perezi" OR "B. pereziellus" OR "B. polaris" OR "B. pomorum" OR "B. pratorum" OR "B. pyrenaeus" OR "B. quadricolor" OR "B. reinigiellus" OR "B. ruderarius" OR "B. ruderatus" OR "B. rupestris" OR "B. saltuarius" OR "B. schrencki" OR "B. semenoviellus" OR "B. sichelii" OR "B. soroeensis" OR "B. sporadicus" OR "B. subterraneus" OR "B. sylvarum" OR "B. sylvestris" OR "B. terrestris" OR "B. vestalis" OR "B. veteranus" OR "B. wurflenii" OR "B. zonatus") Indexes=BCI Timespan=All years
# 1	TS=((Europe* OR Euroregion* OR "Euro region*" OR Austria* OR Belgium OR Belgian OR Bulgaria OR Bulgarian OR Croat* OR Cyprus OR Cypriot* OR Czech* OR Denmark* OR Danish OR Estonia* OR Finland OR finnish* OR France OR French* OR German* OR Greece OR "hellenic republic" OR Greek* OR Hungar* OR Ireland OR Irish OR Ital* OR Latvia OR Lithuania* OR Luxembourg* OR Malta OR maltese* OR Netherlands* OR dutch* OR Poland* OR Polish* OR Portug* OR Romania* OR Slovak* OR Slovenia* OR Spain OR Spanish* OR Swed* OR "United Kingdom" OR Britain OR British OR England* OR English* OR Scotland* OR Scottish OR Wales OR Welsh OR Liechtenstein* OR Iceland* OR Norway* OR Norwegian* OR Switzerland* OR Swiss* OR Albanian* OR Macedonia* OR Montenegro* OR Serbia* OR Bosnia* OR Kosov* OR Benelux OR Czechoslovakia* OR Scandinav* OR Yugoslavia* OR Balkan* OR "Baltic countr*" OR "Baltic state*" OR "Iberian peninsula" OR "Mediterranean countr*" OR "Mediterranean state*" OR "Mediterranean region*" OR "Nordic countr*" OR "Nordic state*") AND (bee OR bees)) Indexes=BCI Timespan=All years

651

652 CAB Abstracts

Set	Query
# 9	(#6) AND LANGUAGE: (English OR Albanian OR Basque OR Breton OR Bulgarian OR Catalan OR Croatian OR Czech OR Danish OR Dutch OR Estonian OR French OR Gaelic OR Galician OR German OR Greek OR Hungarian OR Icelandic OR Interlingua OR Italian OR Latvian OR Lithuanian OR Macedonian OR Maltese OR Norwegian OR Polish OR Portuguese OR Romanian OR Russian OR Serbian OR Serbo-Croatian OR Slovak OR Slovenian OR Spanish OR Swedish OR Unspecified OR Welsh) Indexes=CAB Abstracts Timespan=All years
# 6	#4 AND #5 Indexes=CAB Abstracts Timespan=All years
# 5	TS=("flight span" OR flightspan OR "life expectancy" OR "life history" OR "life span*" OR "life table*" OR "life time" OR lifespan* OR lifetime* OR longevit* OR mortalit* OR survival OR survivorship OR ((colony OR colonies) NEAR/3 (strength OR loss*)) OR ((death OR loss* OR declin*) NEAR/3 (rate* OR population*)) OR (emergence NEAR/3 (fail* OR success*)) OR ((overwinter* OR hiberna*) AND (contract* OR declin* OR loss* OR health OR population*)) OR ((beekeep* NEAR/3 (amateur* OR competenc* OR education OR experience* OR knowledge OR management OR practice* OR professional* OR role OR roles)) AND (health OR stress*))) OR TI=("life cycle") Indexes=CAB Abstracts Timespan=All years
# 4	#3 OR #2 OR #1 Indexes=CAB Abstracts Timespan=All years
# 3	TS=((solitary NEAR/3 (bee OR bees)) OR Afranthidium OR Aglaoapis OR Amegilla OR Ammobates OR Ammobatoides OR Ancyla OR Andrena OR ANDRENIDAE OR ANDRENINAE OR Anthidiellum OR Anthidium OR Anthophora OR APIDAE OR APINAE or Biastes OR

	Camptopoeum OR Ceratina OR Ceylalictus OR Chelostoma OR Chiasmognathus OR Clavipanurgus OR Coelioxys OR Colletes OR COLLETIDAE OR COLLETINAE OR Cubitalia OR Dasypoda OR DASYPODAINAE OR Dioxys OR Dufourea OR Ensliniana OR Eoanthidium OR Epeoloides OR Epeolus OR Eucera OR Flavipanurgus OR Habropoda OR Haetosmia OR HALICTIDAE OR HALICTINAE OR Halictus OR Heriades OR Hofferia OR Hoplitis OR HYLAENIAE OR Hylaeus OR Icteranthidium OR Lasioglossum OR Lithurgus OR Macropis OR Megachile OR MEGACHILIDAE OR MEGACHILINAE OR Melecta OR Melitta OR MELITTIDAE OR MELITTINAE OR Melitturga OR Metadioxys OR (Nomada AND (bee OR bees)) OR NOMADINAE OR NOMIINAE OR Nomiapis OR NOMIOIDINAE OR Nomioides OR Osmia OR Panurginus OR Panurgus OR Paradioxys OR Parammobatodes OR Pasites OR PANURGINAE OR Protosmia OR Pseudoanthidium OR Rhodanthidium OR RHOPHITINAE OR Rhophitoides OR Rophites OR Schmiedeknechtia OR Simpanurgus OR Sphecodes OR Stelis OR Stenoheriades OR Systropha OR Tarsalia OR Tetralonia OR Tetraloniella OR Thrincohalictus OR Thyreus OR Trachusa OR Triepeolus OR Xylocopa OR XYLOCOPINAE) Indexes=CAB Abstracts Timespan=All years
# 2	TS=("managed bee" OR "managed bees" OR "Apis mellifera" OR "Apis mellifica" OR "a mellifera" OR "a mellifica" OR Honeybee* OR "honey bee*" OR Bombus OR Bumblebee* OR "Bumble bee*" OR "B. alpinus" OR "B. argillaceus" OR "B. armeniacus" OR "B. balteatus" OR "B. barbutellus" OR "B. bohemicus" OR "B. brodmannicus" OR "B. campestris" OR "B. cingulatus" OR "B. confusus" OR "B. consobrinus" OR "B. cryptarum" OR "B. cullumanus" OR "B. deuteronymus" OR "B. distinguendus" OR "B. flavidus" OR "B. fragrans" OR "B. gerstaeckeri" OR "B. glacialis" OR "B. haematurus" OR "B. hortorum" OR "B. humilis" OR "B. hyperboreus" OR "B. hypnorum" OR "B. inexspectatus" OR "B. jonellus" OR "B. laesus" OR "B. lapidarius" OR "B. lapponicus" OR "B. lucorum" OR "B. magnus" OR "B. mendax" OR "B. mesomelas" OR "B. mlokosievitzii" OR "B. mocsaryi" OR "B. modestus" OR "B. monticola" OR "B. mucidus" OR "B. muscorum" OR "B. niveatus" OR "B. norvegicus" OR "B. pascuorum" OR "B. patagiatus" OR "B. perezi" OR "B. pereziellus" OR "B. polaris" OR "B. pomorum" OR "B. pratorum" OR "B. pyrenaeus" OR "B. quadricolor" OR "B. reinigiellus" OR "B. ruderarius" OR "B. ruderatus" OR "B. rupestris" OR "B. saltuarius" OR "B. schrencki" OR "B. semenoviellus" OR "B. sichelii" OR "B. soroeensis" OR "B. sporadicus" OR "B. subterraneus" OR "B. sylvarum" OR "B. sylvestris" OR "B. terrestris" OR "B. vestalis" OR "B. veteranus" OR "B. wurflenii" OR "B. zonatus") Indexes=CAB Abstracts Timespan=All years
# 1	TS=((Europe* OR Euroregion* OR "Euro region*" OR Austria* OR Belgium OR Belgian OR Bulgaria OR Bulgarian OR Croat* OR Cyprus OR Cypriot* OR Czech* OR Denmark* OR Danish OR Estonia* OR Finland OR finnish* OR France OR French* OR German* OR Greece OR "hellenic republic" OR Greek* OR Hungar* OR Ireland OR Irish OR Ital* OR Latvia OR Lithuania* OR Luxembourg* OR Malta OR maltese* OR Netherlands* OR dutch* OR Poland* OR Polish* OR Portug* OR Romania* OR Slovak* OR Slovenia* OR Spain OR Spanish* OR Swed* OR "United Kingdom" OR Britain OR British OR England* OR English* OR Scotland* OR Scottish OR Wales OR Welsh OR Liechtenstein* OR Iceland* OR Norway* OR Norwegian* OR Switzerland* OR Swiss* OR Albanian* OR Macedonia* OR Montenegro* OR Serbia* OR Bosnia* OR Kosov* OR Benelux OR Czechoslovakia* OR Scandinav* OR Yugoslavia* OR Balkan* OR "Baltic countr*" OR "Baltic state*" OR "Iberian peninsula" OR "Mediterranean countr*" OR "Mediterranean state*" OR "Mediterranean region*" OR "Nordic countr*" OR "Nordic state*") AND (bee OR bees)) Indexes=CAB Abstracts Timespan=All years

653

654 Scopus

Set	Query
7	#6 AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Portuguese") OR LIMIT-TO (LANGUAGE , "Spanish") OR LIMIT-TO (LANGUAGE , "French") OR LIMIT-TO (LANGUAGE , "Polish") OR LIMIT-

	TO (LANGUAGE , "German") OR LIMIT-TO (LANGUAGE , "Italian") OR LIMIT-TO (LANGUAGE , "Hungarian") OR LIMIT-TO (LANGUAGE , "Swedish") OR LIMIT-TO (LANGUAGE , "Bulgarian") OR LIMIT-TO (LANGUAGE , "Danish") OR LIMIT-TO (LANGUAGE , "Dutch") OR LIMIT-TO (LANGUAGE , "Finnish") OR LIMIT-TO (LANGUAGE , "Norwegian") OR LIMIT-TO (LANGUAGE , "Slovenian") OR LIMIT-TO (LANGUAGE , "Undefined"))
6	#4 AND #5
5	#1 OR #2 OR #3
4	TITLE-ABS-KEY ("flight span" OR flightspan OR "life cycle" OR "life expectancy" OR "life history" OR "life span*" OR "life table*" OR "life time" OR lifespan* OR lifetime* OR longevit* OR mortalit* OR survival OR survivorship OR ((colony OR colonies) W/3 (strength OR loss*)) OR ((death OR loss* OR declin*) W/3 (rate* OR population*)) OR (emergence W/3 (fail* OR success*)) OR ((overwinter* OR hibernat*) AND (contract* OR declin* OR loss* OR health OR population*)) OR ((beekeep* W/3 (amateur* OR competenc* OR education OR experience* OR knowledge OR management OR practice* OR professional* OR role OR roles)) AND (health OR stress*)))
3	TITLE-ABS-KEY ((solitary W/3 (bee OR bees)) OR afranthidium OR aglaoapis OR amegilla OR ammobates OR ammobatoides OR ancyla OR andrena OR andrenidae OR andrenine OR anthidiellum OR anthidium OR anthophora OR apidae OR apinae OR biastes OR camptopoeum OR ceratina OR ceylalictus OR chelostoma OR chiasmognathus OR clavipanurgus OR coelioxys OR colletes OR colletidae OR colletinae OR cubitalia OR dasypoda OR dasypodainae OR {dioxys} OR dufourea OR ensliniana OR eoanthidium OR epeoloides OR epeolus OR eucera OR flavipanurgus OR habropoda OR haetosmia OR halictidae OR halictinae OR halictus OR heriades OR hofferia OR hoplitis OR hylaeniae OR hylaeus OR icteranthidium OR lasioglossum OR lithurgus OR macropis OR megachile OR megachilidae OR megachilinae OR melecta OR melitta OR melittidae OR melittinae OR melitturga OR metadioxys OR (nomada AND (bee OR bees)) OR nomadinae OR nomiinae OR nomiapis OR nomioidinae OR nomioides OR osmia OR panurginus OR panurgus OR paradioxys OR parammobatodes OR pasites OR panurginae OR protosmia OR pseudoanthidium OR rhodanthidium OR rhophitinae OR rhophitoides OR rophites OR schmiedeknechtia OR simpanurgus OR sphecodes OR stelis OR stenoheriades OR systropha OR tarsalia OR tetralonia OR tetraloniella OR thrinco halictus OR thyreus OR trachusa OR triepeolus OR xylocopa OR xylocopinae)
2	TITLE-ABS-KEY ("managed bee" OR "managed bees" OR "Apis mellifera" OR "Apis mellifica" OR "a mellifera" OR "a mellifica" OR honeybee* OR "honey bee*" OR bombus OR bumblebee* OR "Bumble bee*" OR "B. alpinus " OR "B. argillaceus " OR "B. armeniacus " OR "B. balteatus " OR "B. barbutellus " OR "B. bohemicus " OR "B. brodmannicus " OR "B. campestris" OR "B. cingulatus " OR "B. confusus " OR "B. consobrinus" OR "B. cryptarum" OR "B. cullumanus " OR "B. deuteronymus" OR "B. distinguendus" OR "B. flavidus " OR "B. fragrans " OR "B. gerstaeckeri " OR "B. glacialis " OR "B. haematurus " OR "B. hortorum " OR "B. humilis " OR "B. hyperboreus " OR "B. hypnorum " OR "B. inexspectatus " OR "B. jonellus" OR "B. laesus" OR "B. lapidarius" OR "B. lapponicus" OR "B. lucorum" OR "B. magnus" OR "B. mendax" OR "B. mesomelas" OR "B. mlokosievitzii" OR "B. mocsaryi" OR "B. modestus" OR "B. monticola" OR "B. mucidus" OR "B. muscorum" OR "B. niveatus" OR "B. norvegicus" OR "B. pascuorum" OR "B. patagiatus" OR "B. perezi" OR "B. pereziellus" OR "B. polaris" OR "B. pomorum" OR "B. pratorum" OR "B. pyrenaeus" OR "B. quadricolor" OR "B. reinigiellus" OR "B. ruderarius" OR "B. ruderatus" OR "B. rupestris" OR "B. saltuarius" OR "B. schrencki" OR "B. semenoviellus" OR "B. sichelii" OR "B. soroeensis" OR "B. sporadicus" OR "B. subterraneus" OR "B. sylvarum" OR "B. sylvestris" OR "B. terrestris" OR "B. vestalis" OR "B. veteranus" OR "B. wurflenii" OR "B. zonatus")
1	(TITLE-ABS-KEY ((europe* OR euroregion* OR "Euro region*" OR austria* OR belgium OR belgian OR bulgaria OR bulgarian OR croat* OR cyprus OR cypriot* OR

czech* OR denmark* OR danish OR estonia* OR finland OR finnish* OR france OR french* OR german* OR greece OR "hellenic republic" OR greek* OR hungar* OR ireland OR irish OR ital* OR latvia OR lithuania* OR luxembourg* OR malta OR maltese* OR netherlands* OR dutch* OR poland* OR polish* OR portug* OR romania* OR slovak* OR slovenia* OR spain OR spanish* OR swed* OR "United Kingdom" OR britain OR british OR england* OR english* OR scotland* OR scottish OR wales OR welsh OR liechtenstein* OR iceland* OR norway* OR norwegian* OR switzerland* OR swiss* OR albanian* OR macedonia* OR montenegro* OR serbia* OR bosnia* OR kosov* OR benelux OR czechoslovakia* OR scandinav* OR yugoslavia* OR balkan* OR "Baltic countr*" OR "Baltic state*" OR "Iberian peninsula" OR "Mediterranean countr*" OR "Mediterranean state*" OR "Mediterranean region*" OR "Nordic countr*" OR "Nordic state*") AND (bee OR bees)))

Web of Science Core Collection

Set	Query
# 7	(#6) AND LANGUAGE: (English OR Basque OR Bulgarian OR Catalan OR Croatian OR Czech OR Danish OR Dutch OR Estonian OR Finnish OR Flemish OR French OR Gaelic OR Galician OR German OR Greek OR Hungarian OR Icelandic OR Italian OR Latin OR Latvian OR Lithuanian OR Macedonian OR Multiple Languages OR Norwegian OR Polish OR Portuguese OR Provencal OR Romanian OR Russian OR Serbian OR Serbo-Croatian OR Slovak OR Slovenian OR Spanish OR Swedish OR Welsh) Indexes=SCI-EXPANDED, CPCI-S, ESCI Timespan=All years
# 6	#5 AND #4 Indexes=SCI-EXPANDED, CPCI-S, ESCI Timespan=All years
# 5	TS=("flight span" OR flightspan OR "life cycle" OR "life expectancy" OR "life history" OR "life span*" OR "life table*" OR "life time" OR lifespan* OR lifetime* OR longevit* OR mortalit* OR survival OR survivorship OR ((colony OR colonies) NEAR/3 (strength OR loss*)) OR ((death OR loss* OR declin*) NEAR/3 (rate* OR population*)) OR (emergence NEAR/3 (fail* OR success*)) OR ((overwinter* OR hiberna*) AND (contract* OR declin* OR loss* OR health OR population*)) OR ((beekeep* NEAR/3 (amateur* OR competenc* OR education OR experience* OR knowledge OR management OR practice* OR professional* OR role OR roles)) AND (health OR stress*))) Indexes=SCI-EXPANDED, CPCI-S, ESCI Timespan=All years
# 4	#3 OR #2 OR #1 Indexes=SCI-EXPANDED, CPCI-S, ESCI Timespan=All years
# 3	TS=((solitary NEAR/3 (bee OR bees)) OR Afranthidium OR Aglaoapis OR Amegilla OR Ammobates OR Ammobatoides OR Ancyla OR Andrena OR ANDRENIDAE OR ANDRENINAE OR Anthidiellum OR Anthidium OR Anthophora OR APIDAE OR APINAE or Biastes OR Camptopoeum OR Ceratina OR Ceylalictus OR Chelostoma OR Chiasmognathus OR Clavipanurgus OR Coelioxys OR Colletes OR COLLETIDAE OR COLLETINAE OR Cubitalia OR Dasypoda OR DASYPODAINAE OR Dioxys OR Dufourea OR Ensliniana OR Eoanthidium OR Epeoloides OR Epeolus OR Eucera OR Flavipanurgus OR Habropoda OR Haetosmia OR HALICTIDAE OR HALICTINAE OR Halictus OR Heriades OR Hofferia OR Hoplitis OR HYLAENIAE OR Hylaeus OR Icteranthidium OR Lasioglossum OR Lithurgus OR Macropis OR Megachile OR MEGACHILIDAE OR MEGACHILINAE OR Melecta OR Melitta OR MELITTIDAE OR MELITTINAE OR Melitturga OR Metadioxys OR (Nomada AND (bee OR bees)) OR NOMADINAE OR NOMIINAE OR Nomiapis OR NOMIOIDINAE OR Nomioides OR Osmia OR Panurginus OR Panurgus OR Paradioxys OR Parammobatodes OR Pasites OR PANURGINAE OR Protosmia OR Pseudoanthidium OR Rhodanthidium OR RHOPHITINAE OR Rhophitoides OR Rophites OR Schmiedeknechtia OR Simpanurgus OR Sphecodes OR Stelis OR Stenoheriades OR Systropha OR Tarsalia OR Tetralonia OR Tetraloniella OR Thrincohalictus OR Thyreus OR Trachusa OR Triepeolus OR Xylocopa OR XYLOCOPINAE)

	Indexes=SCI-EXPANDED, CPCI-S, ESCI Timespan=All years
# 2	TS=("managed bee" OR "managed bees" OR "Apis mellifera" OR "Apis mellifica" OR "a mellifera" OR "a mellifica" OR Honeybee* OR "honey bee*" OR Bombus OR Bumblebee* OR "Bumble bee*" OR "B. alpinus " OR "B. argillaceus " OR "B. armeniacus " OR "B. balteatus " OR "B. barbutellus " OR "B. bohemicus " OR "B. brodmannicus " OR "B. campestris" OR "B. cingulatus " OR "B. confusus " OR "B. consobrinus" OR "B. cryptarum" OR "B. cullumanus " OR "B. deuteronymus" OR "B. distinguendus" OR "B. flavidus " OR "B. fragrans " OR "B. gerstaeckeri " OR "B. glacialis " OR "B. haematurus " OR "B. hortorum " OR "B. humilis " OR "B. hyperboreus " OR "B. hypnorum " OR "B. inexspectatus " OR "B. jonellus" OR "B. laesus" OR "B. lapidarius" OR "B. lapponicus" OR "B. lucorum" OR "B. magnus" OR "B. mendax" OR "B. mesomelas" OR "B. mlokosievitzii" OR "B. mocsaryi" OR "B. modestus" OR "B. monticola" OR "B. mucidus" OR "B. muscorum" OR "B. niveatus" OR "B. norvegicus" OR "B. pascuorum" OR "B. patagiatus" OR "B. perezi" OR "B. pereziellus" OR "B. polaris" OR "B. pomorum" OR "B. pratorum" OR "B. pyrenaeus" OR "B. quadricolor" OR "B. reinigiellus" OR "B. ruderarius" OR "B. ruderatus" OR "B. rupestris" OR "B. saltuarius" OR "B. schrencki" OR "B. semenoviellus" OR "B. sichelii" OR "B. soroeensis" OR "B. sporadicus" OR "B. subterraneus" OR "B. sylvarum" OR "B. sylvestris" OR "B. terrestris" OR "B. vestalis" OR "B. veteranus" OR "B. wurflenii" OR "B. zonatus") Indexes=SCI-EXPANDED, CPCI-S, ESCI Timespan=All years
# 1	TS=((Europe* OR Euroregion* OR "Euro region*" OR Austria* OR Belgium OR Belgian OR Bulgaria OR Bulgarian OR Croat* OR Cyprus OR Cypriot* OR Czech* OR Denmark* OR Danish OR Estonia* OR Finland OR finnish* OR France OR French* OR German* OR Greece OR "hellenic republic" OR Greek* OR Hungar* OR Ireland OR Irish OR Ital* OR Latvia OR Lithuania* OR Luxembourg* OR Malta OR maltese* OR Netherlands* OR dutch* OR Poland* OR Polish* OR Portug* OR Romania* OR Slovak* OR Slovenia* OR Spain OR Spanish* OR Swed* OR "United Kingdom" OR Britain OR British OR England* OR English* OR Scotland* OR Scottish OR Wales OR Welsh OR Liechtenstein* OR Iceland* OR Norway* OR Norwegian* OR Switzerland* OR Swiss* OR Albanian* OR Macedonia* OR Montenegro* OR Serbia* OR Bosnia* OR Kosov* OR Benelux OR Czechoslovakia* OR Scandinav* OR Yugoslavia* OR Balkan* OR "Baltic countr*" OR "Baltic state*" OR "Iberian peninsula" OR "Mediterranean countr*" OR "Mediterranean state*" OR "Mediterranean region*" OR "Nordic countr*" OR "Nordic state*") AND (bee OR bees)) Indexes=SCI-EXPANDED, CPCI-S, ESCI Timespan=All years

657

658 Zoological Record

Set	Query
# 7	(#6) AND LANGUAGE: (English OR Albanian OR Basque OR Bulgarian OR Catalan OR Croatian OR Czech OR Danish OR Dutch OR Estonian OR Finnish OR French OR Gaelic OR German OR Hungarian OR Italian OR Latvian OR Lithuanian OR Macedonian OR Norwegian OR Polish OR Portuguese OR Provencal OR Romanian OR Serbian OR Serbo-Croatian OR Slovak OR Slovenian OR Spanish OR Swedish OR Welsh) Indexes=Zoological Record Timespan=All years
# 6	#5 AND #4 Indexes=Zoological Record Timespan=All years
# 5	TS=("flight span" OR flightspan OR "life expectancy" OR "life history" OR "life span*" OR "life table*" OR "life time" OR lifespan* OR lifetime* OR longevit* OR mortalit* OR survival OR survivorship OR ((colony OR colonies) NEAR/3 (strength OR loss*)) OR ((death OR loss* OR declin*) NEAR/3 (rate* OR population*)) OR (emergence NEAR/3 (fail* OR success*)) OR ((overwinter* OR hiberna*) AND (contract* OR declin* OR loss* OR health OR population*)) OR ((beekeep* NEAR/3 (amateur* OR competenc* OR education OR

	experience* OR knowledge OR management OR practice* OR professional* OR role OR roles)) AND (health OR stress*))) OR TI=("life cycle") Indexes=Zoological Record Timespan=All years
# 4	#3 OR #2 OR #1 Indexes=Zoological Record Timespan=All years
# 3	TS=((solitary NEAR/3 (bee OR bees)) OR Afranthidium OR Aglaoapis OR Amegilla OR Ammobates OR Ammobatoides OR Ancyla OR Andrena OR ANDRENIDAE OR ANDRENINAE OR Anthidiellum OR Anthidium OR Anthophora OR APIDAE OR APINAE or Biastes OR Camptopoeum OR Ceratina OR Ceylalictus OR Chelostoma OR Chiasmognathus OR Clavipanurgus OR Coelioxys OR Colletes OR COLLETIDAE OR COLLETINAE OR Cubitalia OR Dasypoda OR DASYPODAINAE OR Dioxys OR Dufourea OR Ensliniana OR Eoanthidium OR Epeoloides OR Epeolus OR Eucera OR Flavipanurgus OR Habropoda OR Haetosmia OR HALICTIDAE OR HALICTINAE OR Halictus OR Heriades OR Hofferia OR Hoplitis OR HYLAENIAE OR Hylaeus OR Icteranthidium OR Lasioglossum OR Lithurgus OR Macropis OR Megachile OR MEGACHILIDAE OR MEGACHILINAE OR Melecta OR Melitta OR MELITTIDAE OR MELITTINAE OR Melitturga OR Metadioxys OR (Nomada AND (bee OR bees)) OR NOMADINAE OR NOMIINAE OR Nomiapis OR NOMIOIDINAE OR Nomioides OR Osmia OR Panurginus OR Panurgus OR Paradioxys OR Parammobatodes OR Pasites OR PANURGINAE OR Protosmia OR Pseudoanthidium OR Rhodanthidium OR RHOPHITINAE OR Rhophitoides OR Rophites OR Schmiedeknechtia OR Simpanurgus OR Sphecodes OR Stelis OR Stenoheriades OR Systropha OR Tarsalia OR Tetralonia OR Tetraloniella OR Thrincohalictus OR Thyreus OR Trachusa OR Triepeolus OR Xylocopa OR XYLOCOPINAE) Indexes=Zoological Record Timespan=All years
# 2	TS=("managed bee" OR "managed bees" OR "Apis mellifera" OR "Apis mellifica" OR "a mellifera" OR "a mellifica" OR Honeybee* OR "honey bee*" OR Bombus OR Bumblebee* OR "Bumble bee*" OR "B. alpinus " OR "B. argillaceus " OR "B. armeniacus " OR "B. balteatus " OR "B. barbutellus " OR "B. bohemicus " OR "B. brodmannicus " OR "B. campestris" OR "B. cingulatus " OR "B. confusus " OR "B. consobrinus" OR "B. cryptarum" OR "B. cullumanus " OR "B. deuteronymus" OR "B. distinguendus" OR "B. flavidus " OR "B. fragrans " OR "B. gerstaeckeri " OR "B. glacialis " OR "B. haematurus " OR "B. hortorum " OR "B. humilis " OR "B. hyperboreus " OR "B. hypnorum " OR "B. inexspectatus " OR "B. jonellus" OR "B. laesus" OR "B. lapidarius" OR "B. lapponicus" OR "B. lucorum" OR "B. magnus" OR "B. mendax" OR "B. mesomelas" OR "B. mlokosievitzii" OR "B. mocsaryi" OR "B. modestus" OR "B. monticola" OR "B. mucidus" OR "B. muscorum" OR "B. niveatus" OR "B. norvegicus" OR "B. pascuorum" OR "B. patagiatus" OR "B. perezi" OR "B. pereziellus" OR "B. polaris" OR "B. pomorum" OR "B. pratorum" OR "B. pyrenaeus" OR "B. quadricolor" OR "B. reinigiellus" OR "B. ruderarius" OR "B. ruderatus" OR "B. rupestris" OR "B. saltuarius" OR "B. schrencki" OR "B. semenoviellus" OR "B. sichelii" OR "B. soroeensis" OR "B. sporadicus" OR "B. subterraneus" OR "B. sylvarum" OR "B. sylvestris" OR "B. terrestris" OR "B. vestalis" OR "B. veteranus" OR "B. wurflenii" OR "B. zonatus") Indexes=Zoological Record Timespan=All years
# 1	TS=((Europe* OR Euroregion* OR "Euro region*" OR Austria* OR Belgium OR Belgian OR Bulgaria OR Bulgarian OR Croat* OR Cyprus OR Cypriot* OR Czech* OR Denmark* OR Danish OR Estonia* OR Finland OR finnish* OR France OR French* OR German* OR Greece OR "hellenic republic" OR Greek* OR Hungar* OR Ireland OR Irish OR Ital* OR Latvia OR Lithuania* OR Luxembourg* OR Malta OR maltese* OR Netherlands* OR dutch* OR Poland* OR Polish* OR Portug* OR Romania* OR Slovak* OR Slovenia* OR Spain OR Spanish* OR Swed* OR "United Kingdom" OR Britain OR British OR England* OR English* OR Scotland* OR Scottish OR Wales OR Welsh OR Liechtenstein* OR Iceland* OR Norway* OR Norwegian* OR Switzerland* OR Swiss* OR Albanian* OR Macedonia* OR Montenegro* OR Serbia* OR Bosnia* OR Kosov* OR Benelux OR Czechoslovakia* OR Scandinav* OR Yugoslavia* OR Balkan* OR "Baltic countr*" OR "Baltic state*" OR "Iberian

peninsula" OR "Mediterranean countr*" OR "Mediterranean state*" OR "Mediterranean region*" OR "Nordic countr*" OR "Nordic state*") AND (bee OR bees))

Indexes=Zoological Record Timespan=All years

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