Conservation of honeybees and other pollinators: A global survey

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ABSTRACT

Insect populations are declining globally. Most crops rely on insect pollination, putting food security at risk. Honeybees are important pollinators and have been used widely in public awareness campaigns. This study surveyed countries about the status of their pollinators and programmes for monitoring and management. Responses were received from 273 persons from 108 countries. *Apis mellifera* was reported by nearly all countries. Many countries (72%) routinely collect honeybee data and populations are stable or increasing (77% of countries). Other pollinators receive less attention, although their populations are dwindling in most (70%) countries. Conservation and protection are more commonly practiced for honeybees. Most threats, such as habitat loss and pesticides, are shared by all pollinators. Therefore, conservation measures to decrease these threats would be efficient, provided that competition among species is avoided. Monitoring of pollinator populations should be increased.

Keywords: Conservation, Protection, Honeybee, Pollinator, Population monitoring

INTRODUCTION

Pollinators play critical roles in nature and in food and agriculture. Around 90% of wild flowering plants and 75% of food crops rely on animal pollination. More than 200000 species serve as pollinators, including many bee species. Recent reviews on pollinators include Ollerton (2017) and Rader et al. (2020). The honeybee, particularly the Western Honeybee, *Apis mellifera,* is the best-known pollinator and the most frequently subject to human management.

Like many insect species (Sánchez-Bayo and Wyckhuya 2019) and biodiversity in general (e.g Maxwell et al. 2016), populations of pollinators are declining globally (Potts et al. 2010). This decline threatens both natural ecosystems and agricultural production systems (Rhodes 2018). Concern for this trend prompted the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) to undertake an assessment on pollinators, pollination and food production (IPBES, 2016). The key messages of the assessment highlighted the diversity of pollinators and the importance of pollination from economic, nutrition, sustainability and cultural perspectives. The report noted that many pollinators risk extinction for a wide number of reasons, including pesticide use, diseases and simplification of agricultural landscapes. The IPBES assessment report and/or the phenomena and trends discussed therein have led to the launching of numerous pollinator initiatives on national, regional and global levels (e.g. European Commission 2018; FAO 2020a).

In addition to losses in terms of numbers of pollinators, their genetic diversity is at risk. On the global level, policy-related matters involving agrobiodiversity are addressed by the Commission on Genetic Resources for Food and Agriculture (CGRFA - http://www.fao.org/cgrfa), a specialized body of the Food and Agriculture Organization

(FAO) of the United Nations. Among its work, the CGRFA member countries and technical units of FAO monitor and assess the status of genetic resources for food and agriculture.

For animals, FAO maintains the Domestic Animal Diversity Information System (DAD-IS), which serves as the Clearing House Mechanism of the Convention on Biological Diversity (CBD) for monitoring of animal genetic resources for food and agriculture. Each member nation nominates a "National Coordinator", who is responsible for regularly reporting official population numbers of the livestock breeds within the country. The data in DAD-IS are also used for compiling Indicators 2.5.1b and 2.5.2 of the Sustainable Development Goals, which monitor conservation of agrobiodiversity. Although pollinators are animal genetic resources of importance for food and agriculture, they had neither been considered in the intergovernmental process for these resources nor monitored in DAD-IS, which emphasizes "traditional" livestock species, such as cattle and poultry.

Given the increasing concern for pollinators and their genetic diversity, in 2017 the CGFRA requested FAO to consider including domesticated honeybees and potentially other pollinators into DAD-IS (FAO, 2017). In response to this request, we developed a global survey to collect observed and anecdotal data on the status of world-wide honeybee and pollinator populations, perceived threats and programmes for their conservation and protection. The questionnaire also addressed the existence of programmes for monitoring the status of these species. The objective of this study was to evaluate the results of this survey and draw inferences about pollinator conservation and protection and to support the development of DAD-IS for routine global monitoring of honeybees and possibly other pollinators.

MATERIALS AND METHODS

Data

The survey included 28 questions, divided into three sections: (i) General information, (ii) Honeybees and (iii) General pollinators. The topics of the survey are summarized in Table 1. The general information section included a question about the respondents' professional role regarding honeybees and pollinators, which allowed us to determine if there were any significant associations between a respondent's role and his or her response. The latter two sections requested information on the main honeybee and pollinator species present in the respondent's country, their contributions to food and agriculture, threats to their survival, their observed or perceived population status, and systems for population monitoring and protection and conservation. The questionnaire included yes/no, multiple choice, short answer and free-text questions, as well as questions asking participants to rank responses according to their importance. Some questions (e.g. those regarding honey production and types of pollinated crops) will not be discussed in this article.

The survey was implemented through Google Forms® (https://goo.gl/forms/veNe0krWGcFjmT752) and was open from 28 February to 31 July 2017. English and Spanish versions of the survey were distributed to through several channels: (i) National governments, through invitations to National Coordinators (FAO, 2011); (ii) the Secretariat of the CBD; (iii) networks of IBPES; (iv) the International Federation of Beekeepers Associations; and (v) the Domestic Animal Diversity Network (DAD-Net; http://dgroups.org/fao/dad-net). In addition, for countries where no response was received in the first two months of the survey, scientists with recent publications on pollinators were contacted directly and invited to respond. The final dataset is available at doi.org/10.6084/m9.figshare.12200435.v1.

Analysis

One goal of the data preparation was to obtain a single overall response per country in cases where several responses were received. For yes/no questions about the existence of something, such as a conservation programme, "yes" was assumed to be correct for a given country if at least one such reply was received. We assumed that persons responding "no" were simply unaware of the existence of the object in question. For questions regarding the presence of multiple objects, such as pollinator species or conservation measures, responses from a given country were combined to create a common list. For questions about threats to honeybee and pollinator populations, respondents ranked the three greatest threats from lists. Responses were then weighted according to rank (e.g. 1^{st} = 3 points, 2^{nd} = 2 points, 3^{rd} = 1 point, not chosen = 0 points) prior to analysis.

When evaluating population trends, individual responses were used as the dependent variable (y = 1 for increasing, 0 for steady and -1 for decreasing) in a statistical analysis to study the impact of different factors on trends for both honeybees and pollinators. We used an ordered logistic analysis (R polr function), with geographical region (M49 standard classes); whether or not a monitoring system was reported at country scale; and the professional role of respondents as explanatory factors in the initial model. Factors were then sequentially eliminated and the model that minimized the Akaike Information Criterion (AIC) was chosen as the final model. A similar model and approach was used to assess the importance of the various perceived threats to honeybee and pollinator populations, with the dependent variable being the score of the threat according to its ranking (i.e. y = 0, 1, 2 or 3).

RESULTS

Respondents

A total of 273 responses were received from 108 countries (Figure 1). Multiple responses were received from 62 countries. Figure 1 uses a colour gradient to indicate the number of responses per country. The largest number of responses received from a single country was 12, from Ecuador. For 66 countries (61%), a response was received from a person representing the government.

The responses to the survey were well-representative of global honey production and pollination services. Responses were received from 17 of the 18 largest honey-producing countries and accounted for 90% of the global honey production in 2017 (FAO 2020b). Responding countries covered approximately 85% of the world's land mass (Brinkhoff 2020).

More than half (51%) of survey respondents were scientists. Beekeepers were the next largest category (20%), followed by government officials (11%), veterinarians (9%) and non-governmental organizations (6%).

Species and sub-species reported

All 11 *Apis* species of honeybees were reported in at least one country, i.e. *A. mellifera, cerana, florea, dorsata, laboriosa, nigrocincta, andreniformis, binghami, breviligula, koschevnikovi* and *nuluensis*. The first six of these species were reported to be actively managed in some manner (e.g. for honey production or pollination) in at least one country.

Apis mellifera, was reported present and managed in all but one country (Tonga), and other literature reports its presence there (Chapman et al. 2019). The ubiquity of *A. mellifera* was also reflected by the fact that the species was considered "native" by many respondents from the Americas, despite its origin in the Eastern Hemisphere. The next most-widely reported species was the dwarf honeybee, *A. florea*, present in 21 countries, followed by the Asian honeybee, *A. cerana*, in 16 countries. *Apis cerana* was much more frequently managed (15 countries) than *A. florea* (5).

Eighty-five countries identified local *Apis* sub-species. Twenty-six subspecies of *A. mellifera* were reported, along with various hybrids. *A. m. ligustica, carnica, mellifera and scutellata* were the four most common sub-species.

The survey emphasized bee pollinators, but respondents were asked to indicate other species of importance. Non-*Apis* bees were reported by 101 countries (94%) and managed in 78 countries. The most commonly managed species were bumblebees (*Bombus* spp.), in 60 countries. Some *Bombus* species are raised commercially (e.g. Desjarins et al. 2006; Zhang et al. 2015) Bombus species were followed by stingless bees (*Meliponini* spp. – 25 countries), mason bees (*Osmia* spp. - 19), leafcutter bees (Family Megachiliadae - 17, carpenter bees (*Xylocopa* spp. - 14) and sweat bees (Family Halictidae - 10).

Among non-bee species, butterflies were the most common pollinator, cited by 82 countries (76%). Other pollinators reported by more than half of the countries were flies (63%), wasps (59%), and birds (54%).

With respect to individual species, *B. terrestris* was specifically noted by 19 countries. Other species cited multiple times were *M. rotundata* (11), *B. impatiens* (4) and several *Osmia* species.

Countries had the opportunity to mention particularly important pollinators and pollinated crops. For honeybees, 89 countries indicated pollinated cropss. Among these, 81 (91%) mentioned fruit trees, with tree species depending on geographical location and climate. Other important crops were cucurbit species (35 countries - 39%); brassicas (33; 37%), pulses (22; 24%) and sunflowers (20; 22%). Fewer countries reported specific relationships between crops and non-*Apis* pollinators. The most commonly named combinations were *Bombus* species with tomatoes and other greenhouse crops and Megachiliadae species with leguminous forage crops such as alfalfa and clover.

Monitoring of pollinators

Population monitoring is critical for preventing the extinction of species and managing their genetic diversity. Table 2 shows the numbers of countries with systems for monitoring, distinguishing between honeybees and other pollinators. Monitoring of honeybees was more commonly practiced (78 vs. 44 countries; $p < 0.001$ – Fisher's exact test). This result was notable considering that many more species of pollinators than honeybees were potentially available for monitoring. Various countries have reported national honeybee monitoring programmes (e.g. Porrini et al. 2016; Kulhanek et al. 2017).

Indicating the monitored species was voluntary and was reported by 20 countries. Eighteen countries confirmed monitoring of non-*Apis* bees, including eight countries that monitor one or more *Bombus* species. Butterflies, moths, birds and bats were other species reported by at least one country. Several countries, in Europe especially, mentioned the monitoring of a large range in species.

Respondents were asked to identify the responsible authority monitoring honeybees. While the government was most often cited (61 countries), respondents frequently named more than one entity. Beekeeper associations were reported in 50 countries, and scientists and research organizations in 46 countries. Fewer than 20% of countries rely on a single actor and more than 40% involve all three of these entities. When only a single actor was responsible for monitoring, it was usually the government (10 of 15 instances).

Among the countries that do not monitor honeybees, 28 indicated reasons for this absence. Lack of funding (20 countries) was the most common reason. Multiple responses were accepted; lack of political will (13), lack of awareness regarding the importance of such information (11); and low national priority (11) were also frequently reported.

Trends in populations of honeybees and other pollinators

The distributions of population trends for honeybees and other pollinators according the statistical analysis accounting for effects of global regions are in Figure 2. The AIC was minimized when Region was the only explanatory effect. Therefore, the role of the respondent had no significant impact on his or her response. A substantial difference is evident between population trends of honeybees and other pollinators. Honeybee populations were perceived to be or stable or increasing by more than 50% of respondents in all regions, whereas populations of other pollinators were perceived to be decreasing by at least 50% of the respondents in all regions except Oceania. Among countries with monitoring programmes, around 70% reported decreasing populations of non-honeybee pollinators, whereas 77% reported that honeybee populations were steady or increasing.

The only statistically significant difference ($p < 0.05$) for honeybees was between Northern America and Sub-Saharan Africa. Nearly 90% of respondents from Northern America reported a positive or stable trend, whereas this proportion was just slightly greater than 50% for Sub-Saharan Africa. For other pollinators, the only significant ($p < 0.05$) difference was between Europe and Asia. Most of the respondents from both regions perceived general pollinator populations to be declining, but this view was more common in Europe (87% vs. 56% of respondents).

Specific monitoring of the genetic diversity of honeybees was much less common than monitoring the population status of either honeybees or other pollinators. Only 30 countries (28%) undertake this activity. The questionnaire did not specify whether diversity was defined as within or across sub-species; responses generally referred to monitoring within sub-species. Various approaches were described for this activity. These approaches included pedigree, molecular and morphometric based methods, each of which were reported in five countries, with many countries applying multiple approaches. Among the 25 countries for which a trend in genetic diversity was reported, it was either steady or increasing in 20.

Threats to honeybees and other pollinators

The results of the analysis of perceived threats to honeybees and other pollinators are in Figure 3. Region was again the only significant effect, indicating that professional role of the respondent had no substantial effect the threats he or she perceived to be most important. Regarding honeybees, the main threat identified was the *Varroa destructor* mite. The average score for the threat of *V. destructor* was 1.6 (maximum of 3.0) with significant ($p < 0.05$) regional variation.

The second greatest threat for honeybees was pesticides (1.2); followed by habitat loss and degradation (0.8); and climate change (0.7). Significant ($p < 0.05$) regional differences were observed for seven of the classes of honeybee threats. *Varroa destructor* was the most important threat in Asia, Europe, North Africa and Northern America. Pesticides were the most important in Latin America, habitat loss and degradation in Sub-Saharan Africa, and bacterial and fungal diseases in Oceania.

Regional variability was particularly common among threats involving diseases, pests and parasites. For example, *V. destructor* was reported as the main threat much more frequently in Northern America (2.5) and Europe (2.4) than in sub-Saharan Africa (0.7) and Oceania (1.0). Native African subspecies of *A. mellifera* are less susceptible to *V. destructor* than subspecies native to Europe (e.g. Locke 2016). Among the responding countries from Oceania, *V. destructor* is primarily established only in New Zealand (Iwasaki et al. 2015). Significant regional variation was also present for the importance of habitat loss and degradation, pesticides and climate change.

In addition to differences in species and sub-species of pollinators and pests, regions also differ substantially in beekeeping practices and environments, including crop production environments. For example, the commercial pollination and beekeeping industries are much more important in North America than in Africa, where beekeeping of often informal and often includes the use of natural nesting sites (e.g. Lowore et al. 2018). These factors may impact the relative importance of threats.

For other pollinators, the main perceived threats were habitat loss and degradation (average = 1.7), pesticides (0.8), agricultural intensification (0.8) and climate change

(0.8). Northern Africa, for which pesticides ranked as most threatening, was the only region where habitat loss and degradation was not considered the most important threat. However, regional differences were not significant for any of the threats to general pollinators.

Conservation and protection activities for honeybees and other pollinators

For honeybees, conservation or protection measures were reported for 72 countries (67%) versus only 54 (50%) for other pollinators. No significant differences were observed among the native range of *A. mellifera* (Africa, Europe and the Near East – 70%), *A. cerana* (East and Southeast Asia – 71%) and other countries (58%). A much more substantial association was seen for level of economic development. Among OECD countries, 94% reported protection activities for honeybees, versus 55% for non-OECD countries ($p < 0.0001$). A smaller difference was observed for for conservation activities for other pollinators (66% vs. 42%; $p < 0.04$).

The government is the most common actor for both protection of domesticated honeybees and conservation of wild pollinators, with a slightly greater role (87% of the countries with conservation measures) for other pollinators than for honeybees (83%). Research institutions are the second most important actor for both species groups (56 vs 41 countries for honeybees and other pollinators). Beekeeper organizations were reported to play an active role in protection of honeybees in almost half (52) of countries. Conservation organizations play a role in slightly less than a third of countries for both species groups, with a slightly greater importance (34 vs. 30 countries) for other pollinators.

Figure 4 shows the numbers of countries undertaking various activities to support protection of honeybees and conservation of other pollinators. Research was the most common activity for honeybees, being performed in 64 of the 72 countries reporting some activity. However, research was a complementary activity, no country reported research as the only measure. Conservation of native populations and pesticide regulations were the next most frequently performed activities, in 57 and 55 countries, respectively. The least common activity for honeybees, habitat conservation or restoration, was reported in 43 countries, which was nevertheless more common than any conservation measure for other pollinators. For these species, the six activities in Figure 4 were all being undertaken with similar frequency.

Regarding specific pollinator friendly farming practices (no figure or table), integrated pest management was reported by 43 and 35 countries for the benefit of honeybees and other pollinators, respectively. Planting of hedgerows and flower strips was reported by 42 and 29 countries, for honeybees and other pollinators, respectively. Among activities specific to honeybees, 21 countries take measures to preserve honeybee germplasm and 15 countries own and manage honeybee colonies. For non-honeybee pollinators, 22 countries provide or protect nesting resources.

DISCUSSION

The respondents to this survey had substantial heterogeneity with respect to their professional role dealing with bees and other pollinators, but one clear and perhaps counter-intuitive observation can be made from this survey: Although honeybees tend to receive more attention in awareness campaigns, their true risk of extinction seems to be far less than for other pollinators in general, at least for domesticated honeybee populations.

Honeybees represent only a small fraction of the number of pollinator species, many of which have transboundary geographical ranges. One species in particular, *A. mellifera*, can essentially be found in all of the countries of the world and is sometimes considered a threat to native honeybee species (Teichroew et al. 2017). In China, the distribution of *A. cerana* has decreased by 75% since the introduction of *A. mellifera* (Yang 2005). In most countries (≈80%), the population sizes of honeybees are either known or perceived to be stable or increasing, whereas other pollinators tend to be in decline in most (70%). Honeybee populations are much better monitored (78% vs 43% of countries) and supported by protection programmes (67% vs 50% of countries).

This apparent bias toward protection of honeybees over conservation of other pollinator species, although somewhat counter-intuitive, is perhaps not unusual or unexpected. Several plausible explanations for this bias can be hypothesized. Well-known "flagship" species often receive greater public attention and expenditures for their conservation (e.g. Small 2012; Daniels et al. 2019).

Economic factors also influence protection and conservation activities and spending. First, honeybee pollinator services result in greater crop yields and thus greater economic returns for farmers. Non-honeybee pollinators also provide this service, in some instances superior to honeybees (e.g. Garibaldi et al. 2013), but often in a less-appreciated manner. Second, both honey production and commercial pollination yield substantial returns for beekeepers. Most non-honeybee pollinators contribute to only the first of these revenue-generating activities. Non-honeybee pollinators may have a greater value to pollination of wildflowers than honeybees, but this value is difficult to measure and is a public, rather than private good.

Finally, from a purely numerical and probabilistic standpoint, honeybees (*A. mellifera*, particular) are found in every country of the world, creating a much larger opportunity for their protection than of any single other pollinator species.

Ubiquity, economics and opportunity have also been shown to be associated with protection decisions for domesticated animals (Leroy et al. 2019). National gene banks for livestock tend to have larger collections of more economically important species, particularly cattle. Within species, collections tend to be larger for commercially oriented transboundary breeds than for small local breeds, despite their greater extinction risk.

These results do not necessarily suggest reducing the attention given to protection of honeybees. One reason for the increased recent attention for honeybees is the so-called colony collapse disorder (CCD - Stokstad, 2007). Our survey did not mention CCD specifically, but inquired about colony loss in general. A total of 65 (60%) countries reported annual losses of at least 10% of colonies in recent years and 21 (20%) reported losses exceeding 30%. Such events can devastate a country's pollination services and erode genetic diversity. The reasons for CCD are still not well understood, implying the need for more research (Steinhauer et al. 2018). Although CCD is just one example, research (Figure 4) was the most common honeybee protection activity reported. Decades of research on honeybees has resulted in the development of methods to prevent colony loss and recover colonies through breeding (e.g. Histov et al, 2020; Maucourt et al. 2018). Such research is generally not available for other pollinator species, especially those that are not managed.

In addition, although the presence of *A. mellifera* in every country in the world suggests that extinction of the species is extremely unlikely, individual subspecies are not as secure (De la Rua et al. 2009; Requier et al. 2019) and may be threatened by the more common subspecies.

Commercial pollination services, honey production and the related international trade of honeybee genetic material are dominated by a few *A. mellifera* subspecies, particularly *A. m. ligustica* and *A. m. carnica*, and various hybrids that have favourable genetic and phenotypic characteristics for these tasks. When these subspecies are introduced, they can compete for resources and hybridize with the natives, decreasing their number or diluting their gene pools (for a review, see Mallinger et al. 2017). In this survey, international trade in honeybees was reported by 66 countries. A similar phenomenon threatens the diversity of livestock and crops (FAO 2015) and is one factor that motivated the CGRFA to examine the routine monitoring of pollinators.

The recommended solution to improve the sustainability of pollinators, including honeybees, would be to increase efforts to conserve and/or sustainably use all species. Unfortunately, financial realities may constrain this approach. When possible, protection and conservation measures should be designed to emphasize the truly at-risk species and optimized to benefit both honeybees and other pollinators, as well as other types of biodiversity. The main threats reported were similar between honeybees and other pollinators. With the exception of *V. destructor*, which only affects honeybees, habitat loss and degradation and pesticides were most important threats for both groups of species. Climate change was the next most important threat for both groups. This result implies that many initiatives, if managed correctly, would benefit both groups, even if the primary intention is to bolster honeybee populations. Conserving pollinator diversity may be more beneficial to ecosystems than management for pollination services (Senapathi et al. 2015).

Many protection and conservation measures, including regulations or bans on pesticides, sustainable agriculture practices and increasing public awareness are already being applied. However, less than 40% of countries report targeting these activities toward non-honeybee pollinators. Adoption of practices that too strongly favour one type of pollinator over another must be avoided. Various scientists recommend limiting or prohibiting beekeeping activities in protected areas inhabited by valuable wild pollinators (e.g. Colla and MacIvor, 2017; Geldmann and González-Varo, 2018). Others (e.g. Alaux et al. 2019) have outlined justifications for keeping of native honeybees within protected areas, if properly managed.

Improved monitoring of population status is important. Based on preliminary results of this survey (FAO 2018), in 2019, the CGRFA formally requested FAO to include data fields related to honeybees in DAD-IS. The relative lack of data monitoring systems for other species of pollinators was among the reasons that those species were not included in this mandate, despite their importance and declining populations.

The large number of non-honeybee pollinators and their diversity from country to country are factors that may limit their comprehensive monitoring on national and global levels. Although some countries report monitoring of hundreds of species of pollinators, this may not be feasible for all, especially those with developing economies. FAO and the United Nations Environmental Programme (UNEP) have developed a simple protocol for detecting and monitoring pollinators (LeBuhn et al. 2016) that is being used by 13 countries that responded to the survey.

When monitoring a large number of pollinator species is not feasible, other, more efficient but less comprehensive approaches could be considered. One approach practiced by some countries consists of the designation of indicator species whose population trends mimic those of pollinators in general (Naeem et al. 2020). Butterflies (Brereton et al. 2011) have been proposed as one possible indicator, in part because of their appeal to the public. Citizen science has been investigated as a lower cost approach to gather data to complement standard approaches for insect population monitoring (Dennis et al. 2017). The recently launched World Bee Count (2020) is one such initiative.

For non-honeybee pollinators, details on the status of individual species may be of less interest than the status of all pollinators as a group, on the services they deliver, or on their respective ecosystems. Various scientists have proposed indirect approaches (Sapir et al. 2015) for assessing or predicting the status of pollinators, considering indirect measures and indicators of species abundance. Hegland et al. (2010) developed a cost-effective approach to monitor plant-pollinator networks. Affek (2018) proposed a set of indicators to measure the pollination potential of different ecosystems, while also accounting for potential honey production.

CONCLUSIONS

This study provided information reflecting that although the honeybee, in particular *A. mellifera,* is often used as the flagship species for pollinator conservation, they are generally not at risk of extinction as a species. Honeybee populations were perceived to be or stable or increasing by a majority of respondents in all regions, whereas populations of other pollinators were judged to be declining by most of the respondents in nearly all regions. *A. mellifera* is overwhelmingly the most commonly managed pollinators. Many countries routinely collect honeybee population data and have protection and conservation programmes for *A. mellifera* and other honeybee populations. In a large part of the world, honeybee populations are steady and increasing in numbers.

The survey also revealed the wide disparity in information about and resources dedicated toward honeybees and other pollinators. Honeybees, due to their clear commercial importance, have been widely researched for years in many countries. While some general pollinators are utilized and managed, they are almost all bee species and less is known about other pollinators. These species are less likely to be monitored and conserved than their bee, and specifically honeybee, counterparts. In most countries populations of general pollinators are decreasing.

Honeybees and other pollinators face many of the same risks. Therefore, greater implementation of protection and conservation activities that equitably support the wellbeing of all pollinators is recommended whenever possible. Increased monitoring of pollinator is also warranted. Globally, genetic diversity of pollinators is not widely studied, even in honeybees, although genetic diversity is generally accepted to be vital to species' long-term propagation and health. Even within honeybees, the increasing dominance of highly-productive domesticated *A. mellifera* subspecies puts genetic diversity of that species at risk and may also be detrimental for *A. cerana* and other *Apis* species.

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AUTHOR DECLARATIONS

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FIGURE CAPTIONS

Fig.1 Countries with responses to the survey, with a colour gradient according to the number of responses per country

Fig.2 Reported trends in populations of honeybees and other pollinators according to regions. [Different letters correspond to significantly different trends across regions ($p < 0.05$) after correcting for multiple testing]

Fig.3 Reported threats in populations of honeybees and other pollinators according to regions, ranked on a 0-3 scale. with 3 being the greatest level of threat. (NS: non-significant; * $P<0.05$; ** $P<0.01$; *** $P<0.001$)

Fig.4 Numbers of countries reporting various activities for conservation of honeybees and other pollinators

Table 1 Summary of survey sections and question topics

Questions	Topic
Section 1 – Information about respondents (e.g. country, professional role)	
Section 2 – Honeybees	
Questions	Topic
1	Species and subspecies
2-3	Population data collection
4-5	Honey management
6-8	Population status
9-10	Services
11-13	International trade
14	Services and Products
15	Threats
16	Conservation
17	References
Section 3 – General pollinators	
Questions	Topic
18-19	Species and subspecies
20-21	Services
22	Population data collection
23	Population status
24	Threats
25-26	Species extinct or at risk
27	Conservation
28	References

Table 2 Numbers and proportions (%) of countries with national systems for monitoring of pollinator populations

Status of national systems	Honeybees		Other pollinators	
	N	%	N	%
Existent	78[a]	72	44[b]	41
Non-existent	24	22	55	51
Unknown	6	6	9	8

[a]For nine countries, only some species of honeybees are regularly monitored

[b]For at least one species of pollinator other than *Apis* honeybees

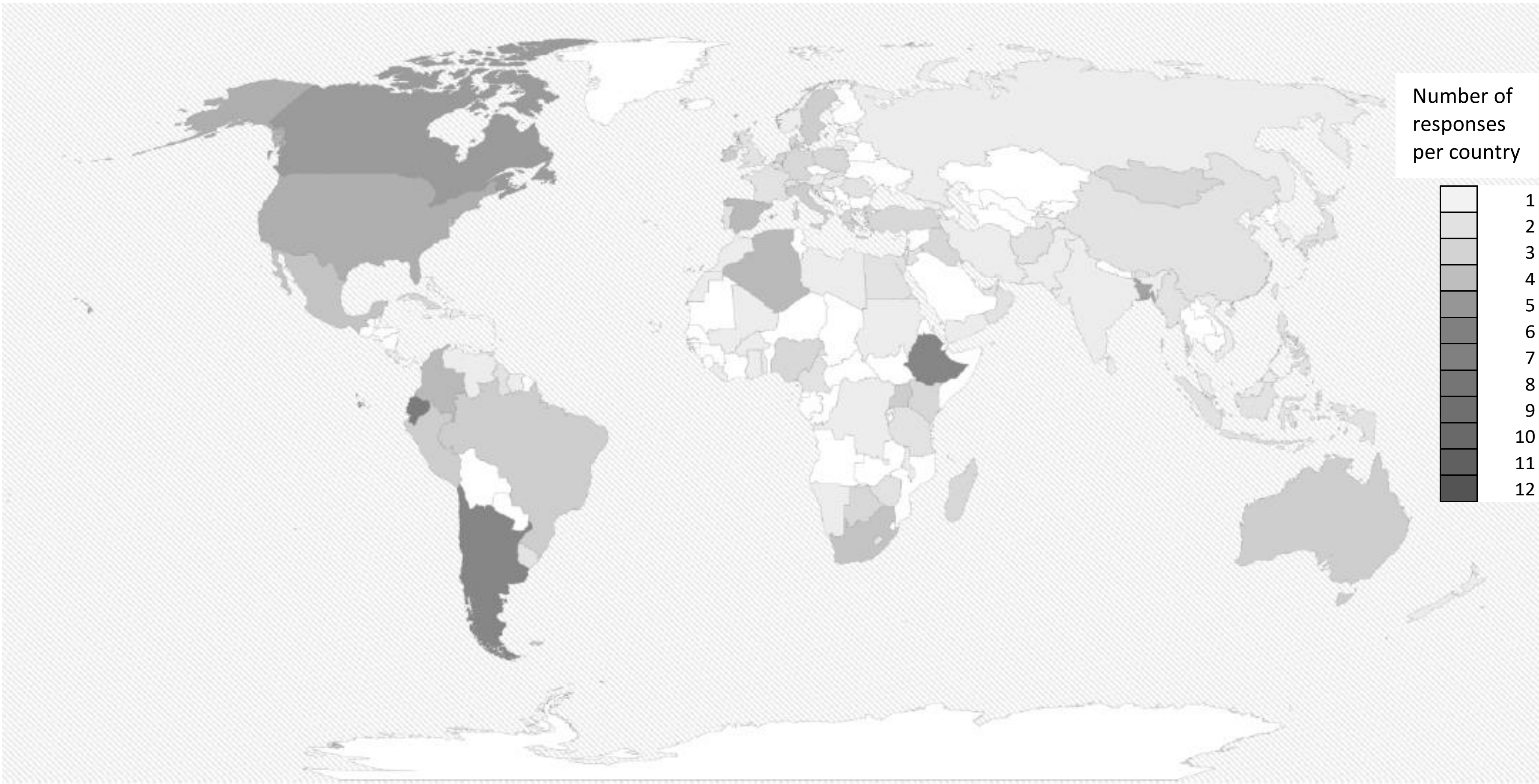

Fig.1 Countries with responses to the survey, with a colour gradient according to the number of responses per country

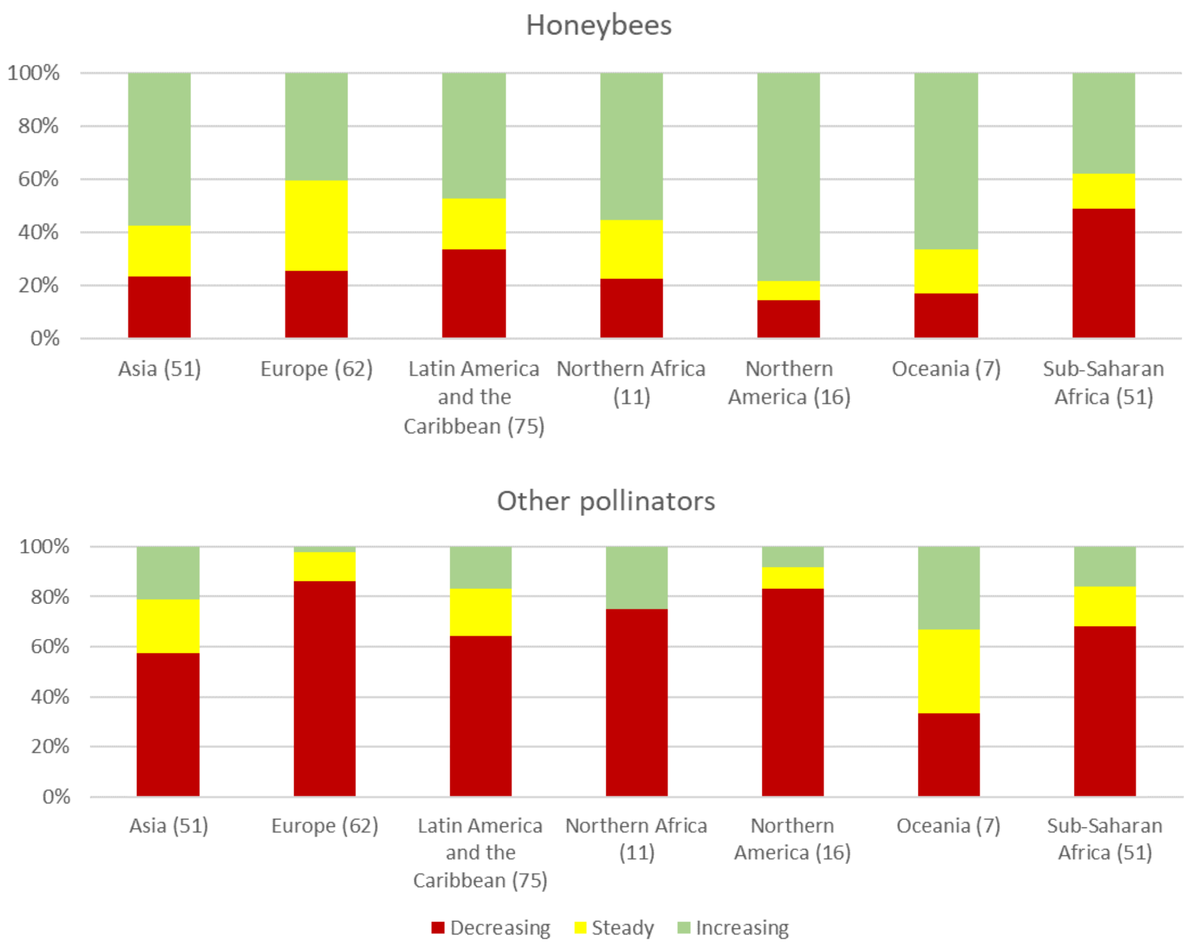

Fig.2 Reported trends in populations of honeybees and other pollinators according to regions. [Different letters correspond to significantly different trends across regions (p < 0.05) after correcting for multiple testing]

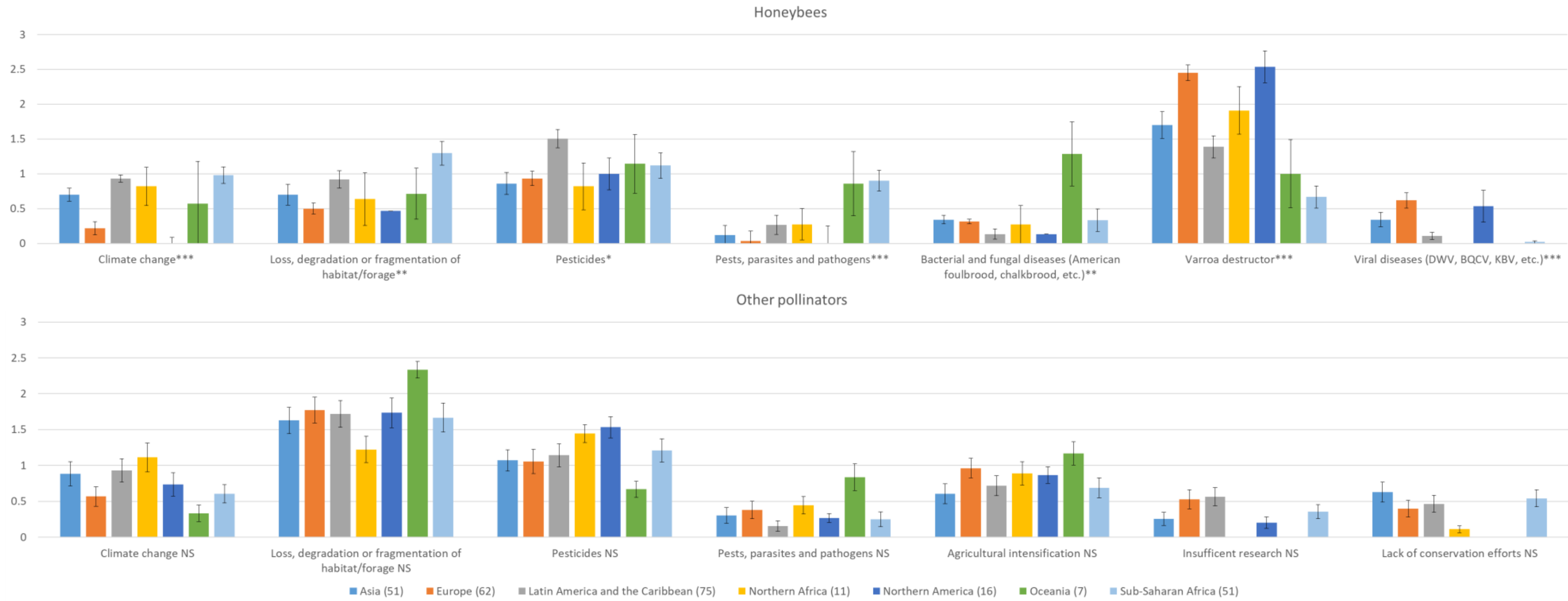

Fig.3 Reported threats in populations of honeybees and other pollinators according to regions, ranked on a 0-3 scale. with 3 being the greatest level of threat. (NS: non-significant; * P<0.05; ** P<0.01; *** P<0.001)

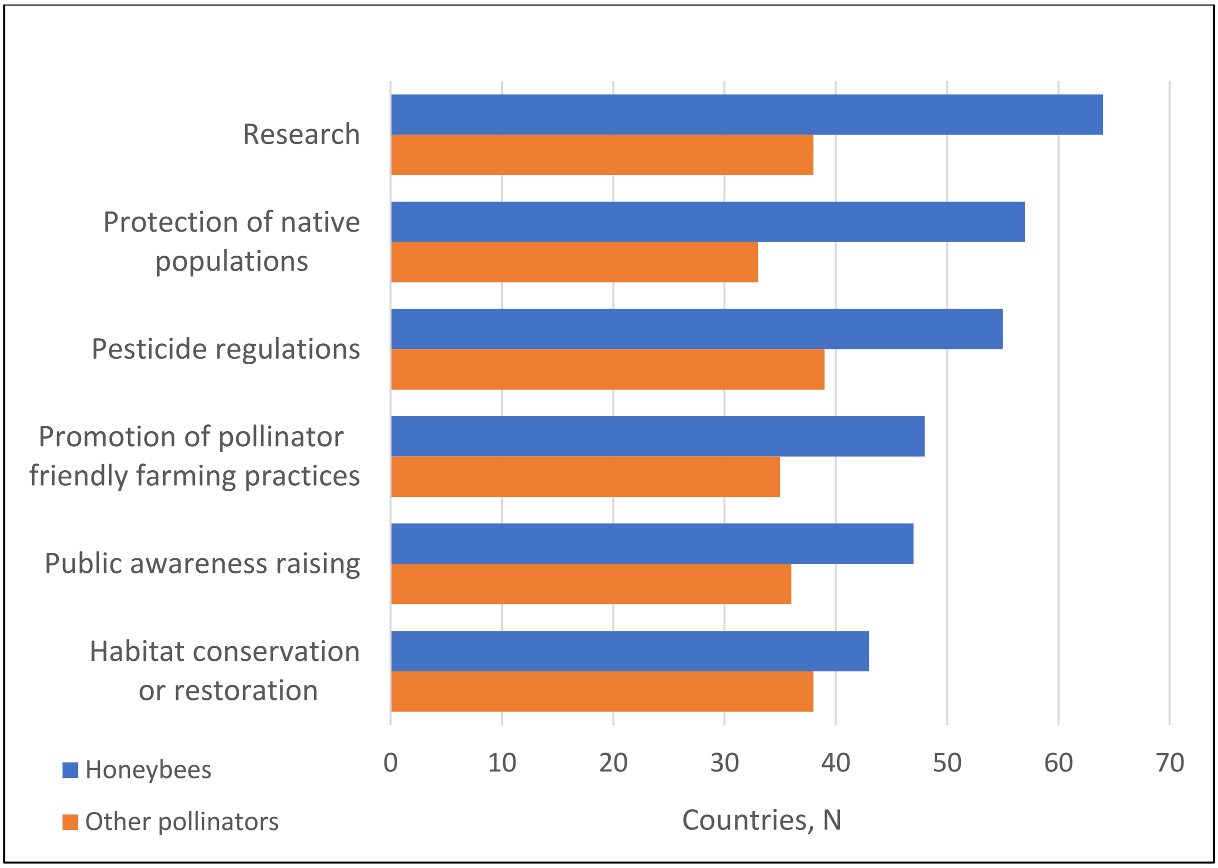

Fig.4 Numbers of countries reporting various activities for conservation of honeybees and other pollinators