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# *Apis mellifera* welfare: definition and future directions

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## 1 Introduction

*Apis mellifera*, commonly known as the Western honeybee, plays a crucial role in providing ecosystem services, such as pollination, which are essential for biodiversity and environmental quality (Stout and Finn, 2015). Honey bees are the most economically valuable pollinator worldwide and impact a wide number of commercial crops and wild plants, some of which are threatened by extinction (Hristov et al., 2020). Hive products are valuable not only for their economic benefits but also for their positive impact on human and animal health (Boppré and Vane-Wright, 2019; Brodschneider and Gratzler, 2021; De Goede et al., 2013). Thanks to its pollination services, *Apis mellifera* is regarded as a flagship species among pollinators and serves as a biomarker for environmental quality (FAO, 2022; Giovanetti and Bortolotti, 2023; Olate-Olave et al., 2021).

Beekeepers promote sustainability and product safety by adopting Good Beekeeping Practices and Biosecurity Measures, following the principles of the One Health approach to achieve collective health for animals, humans, and the environment (Brodschneider and Gratzler, 2021; Lerner and Berg, 2017; Pietropaoli et al., 2020; Rivera-Gomis et al., 2020). However, a more advanced approach to apiculture should incorporate animal welfare considerations, as these represent a key component in the shift towards more sustainable farming practices (Escobar, 2022; Koralesky et al., 2022; Lanzoni et al., 2023; Stamp Dawkins, 2021).

Animal welfare science, a multidisciplinary field involving ethics, laws, physiology, ethology, and farming, is now a significant consideration in modern policies and scientific research (Koralesky et al., 2022; Vapnek and Chapman, 2010). Poor welfare can exist also in animals that appear healthy and productive, and its negative outcomes become evident only when coping mechanisms fail, leading to issues like illness, lack of productivity, infertility,

and behavioral anomalies (Bottaccioli and Rulli, 2014; Fraser, 2008; Moberg, 1985; Sandfoss et al., 2020; Yeates, 2024). Since the beginning of the 21st century, ensuring good levels of animal welfare has shown to improve production outcomes, maintain healthy animals, and reduce intervention costs (Fernandes et al., 2021), while enhancing the living conditions of animals, humans, and the environment in various aspects, including social, health, economic, behavioral, and mental domains (Bayvel, 2004; Beausoleil and Mellor, 2015; Browning, 2022). Several studies have shown that animals living in good welfare conditions not only produce more, but also exhibit better health and fertility. This reduces the costs associated with treating sick or infertile animals, limits the usage of antimicrobial substances and enhances growth and resilience (Blokhuis et al., 2013; Fernandes et al., 2021; Fraser, 2008; Mariottini et al., 2022; Moriconi et al., 2024).

In this context, the One Welfare approach, encouraged by the FAO (Food and Agriculture Organization of the United Nations) and WOAHA (World Organization of Animal Health), is gaining global traction (Baragli et al., 2022; FAO, 2023; Verniers, 2022). This approach advocates for the interconnected and shared welfare of humans, animals, and the physical and social environments (Keeling et al., 2022; Stephens, 2022; Vapnek and Chapman, 2010). Traditional animal welfare is based on the Five Freedoms, which outline the fundamental requirements for contemporary animal farming to satisfy the essential needs of the farmed animals (Blokhuis et al., 2013; Broom, 2008). These include Freedom from hunger and thirst, Freedom from discomfort, Freedom from pain, injury and disease, Freedom to express normal behavior, and Freedom from fear and distress (Brambell, 1965).

The Five Freedoms, initially conceived to protect intensively farmed mammals and birds, have evolved in response to changing public opinion and values regarding animals (Alonso et al., 2020). In recent years, animal welfare science has expanded its focus from avoiding negative impacts to also include providing positive welfare states. Modern practices now emphasize good farming and product standards (Browning and Veit, 2021), based on the more comprehensive Five Domains Model (Beausoleil and Mellor, 2015; Grandin, 2022; Mellor, 2016; Mellor et al., 2020). This approach aims for a state of complete physical, mental, and social well-being, rather than merely the absence of disease or infirmity, considering as significant the welfare of all the stakeholders involved (human, animals and the environment). The model not only addresses the basic needs of the animals, but also emphasizes that animal welfare is a continuum from negative to positive emotional states. It strives to enhance animal welfare by placing greater emphasis on the mental experiences of the animals (Vigors et al., 2021). Despite their remarkable abilities, honey bees have been given limited consideration in terms of welfare due to uncertainty about their capacity to experience mental states. However, based on numerous scientific reports, we believe that honey bees are capable of feelings and emotions, and they align perfectly with the Five Domains model, just like any other animal (Andrews et al., 2024; Chittka, 2022a; Chittka and Geiger, 1995;

Degen et al., 2015; Garrido and Nanetti, 2019; Perry et al., 2017; Solvi et al., 2016; Tan et al., 2013).

The New York Declaration recently acknowledged the realistic possibility of consciousness in invertebrates (Andrews et al., 2024), including *Apis mellifera*, emphasizing the importance of considering their welfare based on scientific evidence<sup>1</sup>. However, animal welfare is applicable once its meaning is clearly defined and practical actions are implemented to measure and to improve specific indicators (Lanzoni et al., 2023; Lorenzi et al., 2023; Sevi, 2009). For *Apis mellifera*, the concept of welfare needs to be further defined, drawing from models that address contemporary threats and promote preventive approaches (Donkersley et al., 2020).

## 1.1 *Apis mellifera* welfare definition: current state and development

The concept of welfare has been explored through various lenses, primarily focusing on either the subjective experiences and consciousness (Experience Welfare) or on the physical health, biological functioning, and the ability of animals to perform natural behaviors (Functional Welfare) (Birch, 2022; Mellor, 2016). By integrating both experience welfare and functional welfare, a more comprehensive understanding of animal welfare can be achieved, ensuring that animals experience both physical well-being and positive emotional states (Reimert et al., 2023). For *Apis mellifera*, applying Experience Welfare can be challenging due to difficulties in reaching consensus on honey bee cognition, which might lead to arbitrary conclusions. However, the recent New York Declaration could help guide the discussion and address this issue. In fact, the welfare of insects in captivity encompasses a complex array of issues, like stress, loss of individual choice, suffering, pain and sentience (Boppré and Vane-Wright, 2019). Sentience, understood as the capacity to experience positive and negative feelings (Birch, 2017), has rarely been considered in traditional beekeeping practices. However, recent studies on invertebrates, including bees, suggest that individual bees as much as the superorganism exhibit distinct personality traits, highlighting the need to pay greater attention to their welfare, especially in the context of intensive, managed apiculture (Mather and Carere, 2019). Given the highly social and interconnected nature of bees, both the collective personality of the colony and the individual experiences of each bee should be acknowledged when they are held in captivity (Pinter-Wollman, 2012). For instance, foraging bees have been shown to exhibit varying personality profiles depending on the areas they forage, which could indicate different levels of stress or well-being in these environments (Chittka, 2022b). Failing to recognize this could lead to unnecessary suffering: sentience is crucial for adapting beekeeping practices to minimize negative experiences and promote positive ones, particularly in captivity where stressors may be heightened. In 2019, Garrido and Nanetti have been at the forefront of defining welfare in managed bees, describing it as the “*most natural condition possible*” under managed circumstances, while considering all potential threats to honeybees (Garrido and Nanetti, 2019).

The responses to stress events characterize the animal's welfare status, which relies on animal's subjective experiences (i.e. sentience). Sentience grants the ability to consciously experience

<sup>1</sup> [www.nydeclaration.com](http://www.nydeclaration.com).

negative or positive sensations, emotions, feelings, or other subjective states that are significant to the animal (Mellor, 2019). Sentience plays a crucial role in understanding the variety of animal welfare status, whether experiences are negative (welfare compromising), or positive (welfare enhancing) (Mellor, 2019). Sentience is recognized in animals regardless of their cognitive capacities, a topic that scientific communities have recently been focusing on, particularly in the case of honeybees (Andrews, 2024; Chittka, 2017; Perry et al., 2017; Wenseleers and Van Zweden, 2017).

The New York Declaration on animal consciousness highlights the realistic possibility of conscious experience in many invertebrates, including insects, and stresses the importance of considering this possibility in welfare decisions (Andrews, 2024). Even in the absence of conclusive evidence of sentience, the precautionary principle and the Terrestrial Animal Code (WOAH, 2013), along with the Animal Welfare Act, grant welfare considerations to all animals (Birch, 2017; Knutsson and Munthe, 2017; Lundmark et al., 2013).

Thus, animal welfare assessments should be carried out also in the beekeeping sector and the methods used can be supported by established Good Beekeeping Practices and Biosecurity Measures and can benefit from comprehensive data and insights from surveys, studies, beekeeper experiences, and in-hive monitoring (Precision Beekeeping). In order not to overlook the relationship between environmental stressors and animals' stress-responses, the use of both Resources-Based Indicators and Animal-Based Indicators to assess honeybee welfare, appears to be the most suitable solution (Montagnin et al., 2024; Moriconi et al., 2024). For *Apis mellifera* such approach has been already used in research projects in Europe, like BEE-WELL (Italian Ministry of Health, 2022) and CLASSYALV (Montagnin et al., 2024).

## 1.2 *Apis mellifera* welfare definition: author's vision

With the New York Declaration regarding honey bee sentience now addressed, we can incorporate Stamp Dawkins' recent statement on animal preferences to refine our understanding of bee welfare (Stamp Dawkins, 2021). Marian Stamp Dawkins suggested that an animal in good welfare is healthy and “has what it wants”, indicating a positive state of preference defined as “valence state” (Birch, 2022; Stamp Dawkins, 2023, 2021). The latter is a neutral status, functionally positioned between consciousness and non-consciousness, where animals process information, make choices for their best interests, and express preferences based on the environmental options available to them. Many bee species have demonstrated such capacities (Menzel, 2021), exhibiting behaviors indicative of desire, curiosity (Degen et al., 2015) playfulness (Galpayage Dona et al., 2022), anxiety, and despair (Bateson et al., 2011; Schönfelder and Bogner, 2017; Tan et al., 2013; Wehmann et al., 2015). In bees, affective states were reported to influence decision-making, just as they do in humans and other vertebrates. While the neurophysiological mechanisms are probably

different, the resulting decision-making behavior appears similar (Mendl et al., 2011). Thus, the study of emotion-like patterns in bees is becoming an increasingly important topic within the scientific community (Baracchi et al., 2017; Chittka, 2017; Chittka and Geiger, 1995; Mendl and Paul, 2016; Perry et al., 2017; Perry and Baciadonna, 2017; Solvi et al., 2016).

Stamp Dawkins's definition of animal welfare aligns with the fundamental needs outlined in many scientific and ethical declarations (Stamp Dawkins, 2021). The most prominent of these is the Five Freedoms enunciated in the Brambell Report (Brambell, 1965; Carenzi and Verga, 2009; Webster, 2001) and later by the British Farmed Animal Welfare Council (FAWC) in 1979. However, since its inception, animal welfare science has made significant progress, going beyond the basic needs of animals to also include positive experiences, as highlighted in the Five Domains model. In addition, the widely recognized One Welfare approach emphasizes the interconnected welfare of humans, animals, and the environment (Fraser and MacRae, 2011; Koralesky et al., 2022; Lanzoni et al., 2023; McGreevy et al., 2020; Pinillos, 2018; Stephens, 2022), and organizations like FAO (2009), WOAH (2024), and the European Commission- EUPAHW (2024) are actively supporting initiatives to advance this approach.

Based on these considerations, we propose a novel welfare definition for *Apis mellifera* that follows a functional approach: “a balanced and dynamic state, as natural as possible, where the beehive superorganism and each individual bee have the freedom to express their roles and preferences, meet their fundamental needs, and adapt positively to variable external stressors without enduring unnecessary suffering”. This definition captures the essence of honey bee welfare, acknowledging both individual and colony-level needs and emphasizing adaptability and natural living conditions.

Honey bees have only recently been considered within the scope of Animal Welfare (Garrido and Nanetti, 2019), and there was still no clear definition that apply welfare principles. Due to limited knowledge about the cognitive world of bees, the scientific community has long been skeptical about the necessity of considering welfare in invertebrates (Perry et al., 2017). Thanks to the New York Declaration, scientific research, and growing public and institutional awareness, solid foundations have been established to approach welfare in honey bees, accounting their consciousness and acknowledging the extraordinary abilities of their minds (Baracchi et al., 2017; Boppré and Vane-Wright, 2019; Chittka, 2022a, 2017; Perry and Baciadonna, 2017; Pinter-Wollman, 2012; Solvi et al., 2016), as we did in this work. Acknowledging the complex interplay of colony dynamics and individual experiences our definition is flexible and applicable to various scenarios, including experimental, breeding, and non-traditional beekeeping. This opinion piece offers a focused perspective on what welfare means for honey bees fostering narrow actions to make progress in beekeeping practices, aligning apiculture with the One Welfare framework for the first time. Additionally, this definition introduces the welfare's functional approach for honey bees, opening roads to viable actions for control, assessments and measurements, such as welfare indicators and to improvements, such as identification of honey bee welfare practices.

### 1.3 *Apis mellifera* welfare definition: future directions

In our opinion, we believe that a functional definition of Honey Bee Welfare is essential for advancing beekeeping practices and honey bee research. Nowadays, beekeeping cannot disregard animal welfare and it must provide a clear and actionable framework to endure good living conditions of *Apis mellifera* (Garrido and Nanetti, 2019). Applying welfare principles to honey bees involves addressing their ability to cope with stress (Even et al., 2012; Jhawar et al., 2023), maintain balance, and express preferences (Chittka, 2017; Stamp Dawkins, 2023; Rault et al., 2020; Stamp Dawkins, 2021) within a biocentric framework. This approach not only enhances our understanding of honey bees but also opens the door to increasing general knowledge about their needs and well-being. By integrating beekeeping with the principles of the Five Domains model into a comprehensive, multi-level, and interdisciplinary approach, under the One Welfare perspective, apiculture can become more welfare-oriented. Developing a welfare-friendly beekeeping sector begins with a clear understanding of what constitutes the good life for *Apis mellifera* and redefining its needs through this novel welfare definition. This approach not only advocates for honey bee resilience but also aligns with the broader goal of creating a balanced world. Establishing this new definition of Honey Bee Welfare will clarify their role within a shared future context (Fraser, 2019) and support the development of policies and regulations that reflect the latest scientific and ecological knowledge, as well as contemporary attitudes towards managed animals.

Future research directions should focus on refining and validating welfare indicators specific to honey bees, considering both individual bees and the colony as a superorganism. This includes developing new methodologies for assessing bee health, behavior, and environmental interactions (Papa et al., 2022), and creating welfare assessment tools that can be easily used by beekeepers and sector operators, like entomologists, veterinarians, ecologists, and social scientists. Interdisciplinary collaborations will be crucial in addressing the multifaceted challenges of honey bee welfare. Emphasizing the role of technology in monitoring and improving bee welfare, such as through the use of sensors and artificial intelligence, can also provide real-time data and insights (Danieli et al., 2023). Policymakers should be informed by this research to establish guidelines and standards that promote

sustainable and welfare-oriented beekeeping practices. Education and outreach programs for beekeepers and the public will be vital in fostering a culture of welfare awareness and encouraging the adoption of best practices. Ultimately, advancing honey bee welfare will contribute to the health and stability of ecosystems, benefiting both biodiversity and human societies.

### Author contributions

GF: Conceptualization, Writing – original draft, Writing – review & editing, Supervision. EG: Conceptualization, Writing – original draft, Writing – review & editing. CR: Supervision, Writing – review & editing. VL: Supervision, Writing – review & editing. GB: Supervision, Writing – review & editing.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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