

Article

Definition and Identification of Honey Bee Welfare Practices Within the Five Domains Framework for Sustainable Beekeeping

Giovanni Formato ¹, Elena Giannottu ^{1,*}, Valentina Lorenzi ², Cristina Roncoroni ¹, Marco Pietropaoli ¹, Camilla Pedrelli ¹, Marina Bagni ³ and Stefano Palomba ¹

¹ Istituto Zooprofilattico Sperimentale del Lazio e della Toscana “M. Aleandri”, International Cooperation and Research for Sustainable Development in Beekeeping Laboratory, FAO Reference Centre “Animal Health and Food Security Discipline Apiculture, Health and Biosecurity”, WOAHC Collaborating Centre “Good Beekeeping Management Practices and Biosecurity Measures in the Apiculture Sector”, Via Appia Nuova 1411, 00178 Rome, Italy; giovanni.formato@izslt.it (G.F.); cristina.roncoroni@izslt.it (C.R.); marco.pietropaoli@izslt.it (M.P.); camilla.pedrelli-esterno@izslt.it (C.P.); stefano.palomba@izslt.it (S.P.)

² Italian Reference Centre for Animal Welfare (CReNBA), Istituto Zooprofilattico Sperimentale della Lombardia e dell’Emilia-Romagna “B. Ubertini”, Via Antonio Bianchi, 7/9, 25124 Brescia, Italy; valentina.lorenzi@izsler.it

³ Direzione Generale della Salute Animale, Ufficio 2, Ministero della Salute, Viale Giorgio Ribotta 5, 00144 Rome, Italy; m.bagni@sanita.it

* Correspondence: giannottue@gmail.com; Tel.: +39-3382221832

Featured Application: The main applications of this article include integrating Honey Bee Welfare Practices (HBWPs) into beekeeper training programs, developing sustainability policies and standards, creating technological monitoring tools, conducting welfare audits, fostering environmental partnerships, and supporting ongoing research, promoting a sustainable impact aligned with the One Welfare framework.

Abstract: This paper aims to define and identify the Honey Bee Welfare Practices (HBWPs) that beekeepers should adopt within a modern framework for sustainable apiculture. Once identified, HBWPs were categorized according to the Five Domains Model used in other animal species. Drawing on findings of the European BPRACTICES Horizon 2020 project, we identified, for the first time, 243 HBWPs: while all practices were considered impacting the *mental state* domain, 38 were assigned to *nutrition/hydration*, 90 to *environment*, 220 to *health*, and 50 to *behavior*. The proposed HBWPs aim to fill existing gaps by introducing a new approach that more fully respects honey bee behavior and helps prevent unnecessary suffering for each bee and the whole beehive at the same time. Future efforts should focus on maximizing welfare benefits within the One Welfare framework, moving beyond the previously considered One Health perspective. This welfare-oriented focus benefits honey bees, supports beekeepers, and promotes environmental sustainability, aligning with the principles of One Welfare.

Keywords: *Apis mellifera*; honey bee welfare practices; definition; domains; identification



Citation: Formato, G.; Giannottu, E.; Lorenzi, V.; Roncoroni, C.; Pietropaoli, M.; Pedrelli, C.; Bagni, M.; Palomba, S. Definition and Identification of Honey Bee Welfare Practices Within the Five Domains Framework for Sustainable Beekeeping. *Appl. Sci.* **2024**, *14*, 11902. <https://doi.org/10.3390/app142411902>

Academic Editor: Thorsten Schwerte

Received: 31 October 2024

Revised: 10 December 2024

Accepted: 12 December 2024

Published: 19 December 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

The welfare of honey bees (*Apis mellifera*) has received significant attention due to their crucial roles in agroecosystems, such as pollination, serving as bioindicators, producing hive products, and their use in Api tourism and apitherapy [1–8]. Food production is heavily reliant on bees, as more than 80% of plants are pollinated by honeybees, and some plants cannot reproduce without their pollination. Additionally, the well-being of bees is directly linked to improved honey production, highlighting the importance of maintaining their health [1–8].

Bee welfare is an important topic for both the ecosystem and the economy, as bees are essential for pollinating many cultivated and wild plants. Bee welfare refers to maintaining optimal conditions for their health and survival requiring sustainable beekeeping

management practices [9]. In fact, sustainable beekeeping refers to the implementation of bee-friendly practices aimed at addressing the various threats to honeybee health, including pests, predators, chemicals, inadequate management practices, climate change, and other stressors. This involves a holistic approach that extends beyond the apiary, considering the surrounding environment and all relevant stakeholders. This approach prioritizes the long-term health and well-being of bee colonies, ensuring their resilience and productivity while promoting ecological balance and sustainability in beekeeping practices [10].

Several factors affect bee welfare, mainly nutritional stress, loss of habitat, climatic changes, improper use of PPPs (phytosanitary products), diseases and wrong management.

In terms of nutrition, bees require a diverse diet to maintain optimal health. However, this is increasingly threatened by habitat loss. Urbanization, deforestation, and intensive agricultural practices contribute to the loss of natural habitats, limiting bees' access to essential food and water sources and shelter [10]. Monoculture practices and insufficient floral diversity can lead to malnutrition, weakening honey bee resilience to diseases and environmental stressors [11]. Climate change, characterized by shifts in temperature patterns and irregular precipitation, disrupts the availability of forage and affects bees' ability to pollinate and survive seasonal transitions, thereby disturbing their life cycles [12,13]. The improper use of certain PPPs, particularly neonicotinoids, has been shown to negatively affect bees by disrupting their nervous systems, impairing navigation and reproduction, and increasing mortality rates [14,15]. Bee colonies are also highly susceptible to parasites, such as the *Varroa destructor* mite, and pathogens, including *Nosema* and various viruses, which together contribute to significant colony declines and collapse [16]. Finally, effective hive management, which includes the control of diseases and parasites as well as providing supplemental feeding during critical periods, is crucial to maintaining the health and productivity of bee colonies [14,15]. As challenges facing bee populations continue to grow, it is crucial to adopt comprehensive approaches to ensure their health and welfare, guiding beekeepers in their activities through the application of Good Beekeeping Practices (GBPs) and Biosecurity Measures in Beekeeping (BMBs).

Rivera Gomis et al. described GBPs as “all the integrative activities that beekeepers apply in on-apiary production to ensure optimal health for humans, honey bees, and the environment” [17,18]. Additionally, Pietropaoli et al. defined BMBs as “all operational activities to reduce the risk of introduction and/or spread of specific honey bee disease agents” [18]. This definition follows valuable models, such as the traditional One Health approach; however, a shift toward more holistic and modern frameworks, such as One Welfare, that describes the interconnection between animal welfare, human well-being and their physical and social environment as important elements to consider in the elaboration and implementation of policies and activities related to each of these aspects, became necessary [19–21]. In this approach, a balanced compromise between honey bees, humans, and environmental well-being is recognized as fundamental [7,19,20].

Although there is no consensus within the scientific community on insect consciousness [13], the precautionary principle assumes that all animals, including honey bees, are sentient and capable of experiencing suffering and emotions [21]. This view has recently been reinforced by the New York Declaration of Consciousness, which acknowledges the realistic possibility of honey bee consciousness and emotional capacities [22] and the need to grant honey bee welfare in beekeeping. The concept of Honey Bee Welfare (HBW) was first defined by Garrido and Nanetti in 2019. They described the welfare of managed honey bees as maintaining “*the most natural condition possible*”, while considering all potential threats to honey bees. Although this definition is valuable, it lacks a positive application of welfare principles for bee life improvements and does not consider the individual experiences of bees or the precautionary principle. We amplified the honey bee welfare concept and defined reared honey bee welfare as “*a balanced and dynamic state, as natural as possible, in which the beehive superorganism and each individual bee have the freedom to express their roles and preferences, meet their fundamental needs, and adapt positively to external stressors without experiencing unnecessary suffering*”.

This definition aligns with current welfare models used for other livestock species, particularly the Five Domains Model [23].

In major livestock species, animal welfare science has significantly improved our understanding of animal welfare. Welfare is assessed by utilizing multiple indicators to measure various aspects of well-being [23]. In particular, the Five Domains Model for animal welfare is currently used across different animal sectors. The model emphasizes the significance of both negative and positive emotions and offers a structured and comprehensive approach to evaluating and improving welfare [24]. The Five Domains Model evaluates the animal's well-being across five key areas: nutrition, environment, health, behavior, and mental state [25]. The latter illustrates the impact of the first four domains on the animal. For instance, the scarcity of food, which affects the nutrition domain, is reflected in the mental domain as a state of 'hunger', representing the animal's subjective experience (or feeling) of the event [23,24,26]. In fact, this model considers both, physical and emotional state, and their interconnections [25,27–31]. Although the Five Domains Model has not yet been applied to beekeeping, it can offer a structure to facilitate the implementation of targeted welfare practices in this field [25]. Considerations of honey bee mental state are supported by the recognition of their sentience and by the recent New York Declaration [22]. Honey bee mental state can be assessed by observing the colony's response to stimuli, treating the superorganism as an individual entity, just as one would consider a single bee.

In this paper, we established the first definition of HBWPs and applied the Five Domains Model to categorize practices that support not only honey bee survival and productivity but also their overall welfare, along with benefits for humans and the environment, thereby promoting a more sustainable, welfare-oriented approach to modern beekeeping.

2. Materials and Methods

In the present study, after defining and listing the HBWPs, we categorized them according to the existing literature about relevant topics for honey bee Welfare, such as the Five Domains Model, sustainable beekeeping practices, and scientifically validated approaches. To list the practices, we referred to the One Health approach, used to identify the 140 GBPs [32] and the 84 [18] already validated through the European BPRACTICES Horizon 2020 project (<https://www.izslt.it/bpractices/>, accessed on 16 July 2024) in collaboration with European beekeepers, international federation of beekeepers association of APIMONDIA, and research Institutes. Additionally, we included previously unlisted practices to ensure comprehensive coverage of all aspects of honey bee welfare. These practices were identified through a detailed review of scientific literature and consultations with experts, with a particular focus on addressing honey bee behavior and minimizing suffering. The inclusion process also considered practices that could complement the existing validated ones to provide a holistic approach to honey bee welfare.

Regarding the headings of the practices, we adhered to those already established. The 140 Good Beekeeping Practices (GBPs) were organized into six categories [17]: general apiary management (including transportation, hygiene, bee health, apiary management, wintering, human health, and colony management), veterinary medicines, disease management, hygiene, animal feeding and watering, and record keeping [17]. In contrast, BMBs were organized under five headings corresponding to the main honey bee diseases in Europe [18]: Varroosis; American Foulbrood, European Foulbrood, Nosemosis and Aethinosis. Finally, we categorized the HBWPs according to the domains *nutrition/hydration* (N), *environment* (E), *health* (H), *behavior* (B), and *mental domain* (M) as usually performed for the other animal species. We also used bold characters to indicate the domain we considered to be most significantly affected compared to the others.

3. Results

Keeping in mind our functional approach of HBW [33], we defined HBWPs as “all those operational activities that aim to implement positively best living conditions for honey bees, pursuing optimal welfare for humans, animals and the environment”.

A total of 243 practices (see Annex) were classified as HBWPs, expanding on those previously identified in GBPs and BMBs within the BPRACTICES project. In addition, 28 new practices, primarily focused on preventing unnecessary suffering and addressing honey bee behaviors (Table 1), were introduced to ensure comprehensive coverage of honey bee welfare, as they had not been covered in the BPRACTICES project. Each practice was evaluated to confirm its alignment with the HBWP definition and to determine its corresponding domain (see Appendix A Table A1).

Table 1. New Honey Bee Welfare Practices identified.

Honey Bee Welfare Practices		Honey Bee Welfare Domain
1.	Ensure that honey bees are housed under optimal physiological conditions, including temperature and humidity control	E/B/M
2.	Locate the hive in a biodiverse area with a variety of melliferous and nectareous plants, as well as bushes that provide natural foraging and swarming opportunities for honey bees	E/B/N/H/M
3.	Locate the hive avoiding light pollution, and excessive vibrations	E/H/N/M
4.	Locate the hives avoiding excessive chemical pollution PPPs	E/H/N/M
5.	Maintain appropriate distances between different apiaries	H/E/N/B/M
6.	Ensure proper hive density per area	H/E/B/M
7.	Prefer to place apiaries at a lower height than the foraging area, allowing foragers carrying nectar and pollen to return to their hive without fatigue	E/M
8.	During transport, ensure that bees are exposed to minimal mechanical stress by scheduling stopovers to allow rest and recover	H/E/M
9.	Prioritize gentle beekeeping practices during inspections preventing unnecessary suffering during inspections (e.g., by avoiding abrupt or sudden movements; using well-fitted latex gloves; lifting or moving combs/frames carefully; avoiding bee crushing, e.g., when closing the hive top, using the smoker properly)	H/B/M
10.	Avoid rearranging the order of combs unless necessary	B/E/H/M
11.	Avoid moving hives unless necessary	E/B/N/M
12.	Do not open the hive at night or when it is rainy or windy	B/H/E/M
13.	Breed your own autochthonous, locally adapted queens	E/H/B/M
14.	Be cautious when handling the queen (e.g., avoiding damaging her or displacing her outside the hive)	H/B/M
15.	Confine the queen in a way that allows her to move freely and lay eggs	B/H/M
16.	Do not replace the queen	H/B/M

Table 1. Cont.

	Honey Bee Welfare Practices	Honey Bee Welfare Domain
17.	Explore alternative methods for identifying the queen without marking her with metal disks or painting her thorax	H /B/M
18.	Do not perform artificial insemination	B /H/M
19.	Do not perform genetic selection	B /H/M
20.	Adopt effective techniques to control honey bee predators (such as wasps, bee-eaters, ants, rats, and bears)	H /E/B/M
21.	Administer varroacide treatments using active ingredients that prioritize bee welfare, such as those with lower toxicity for honey bees	H /M
22.	Do not perform drone brood removal	H /B/M
23.	Monitor honey bee behaviors, including flight activity, noise levels, aggression, calmness, and other emotional states	B /H/M
24.	If bees show signs of agitation, restlessness, or aggression, wait until they have calmed down before continuing with inspections	B /H/M
25.	Respect the natural bee space between combs and remove any abnormal comb constructions	B /E/M
26.	Encourage the natural construction of wax combs in the spring	B /E/M
27.	Communicate with other stakeholders (e.g., beekeepers, farmers, advisors, veterinarians) in the area to coordinate actions for managing foraging resources	E /N/H/M
28.	Attend personal training on One Welfare, with a focus on Honey Bee Welfare	B /E/H/N/M

N = nutrition; E = environment (inside and/or outside the hive); H = health; B = behavior; M = mental state. In bold is the main domain affected.

We adapted to honey bees the Five Domains, identifying challenges and opportunities concerning their welfare. The results are shown in Table 2.

After a detailed analysis of the 243 identified HBWPs, all practices were considered relevant to the mental state domain (M), 42 were assigned to the nutrition/hydration domain (N), 94 to the environment domain (E), 217 to the health domain (H), and 50 to the behavior domain (B) (Table 3). During the allocation, each HBWP could be assigned to more than one domain (Table 3).

Table 2. A description of the Five Domains Model, adapted to managed honey bees (Harvey et al. [13], modified).

DOMAIN 1 Nutrition/hydration Challenges: restricted feed, food and water intake; low feed, food and water quality. Opportunities: Sufficient and good quality of food, feed and water, varied and preferred shapes, colours, smells.		→	DOMAIN 5 Mental state NEGATIVE Thirst, hunger, breathlessness, general (thermal, physical, etc.) discomfort, sickness, exhaustion, frustration, loneliness, isolation, lack of control or security, anxiety, fear, and pain. POSITIVE Rewarding engagement in exploration and foraging; general comfort (thermal, physical, etc.); calmness and liveliness.	HONEY BEE WELFARE STATUS
DOMAIN 2 Environment Challenges: Internal or external discomfort (housing): extreme heat or cold, lack of shade, extreme humidity, lack of internal space within the hive, challenging flying and foraging areas (e.g., physical obstacles, excessive distance from the hive, monoculture /non-melliferous plants, presence of competitors), or predatory threats (bears, birds, wasps, hornets, etc.); poor quality of air/soil /water; anthropogenic pollution (pesticides, electromagnetic fields). Opportunities: Internal or external comfort (housing): thermal comfort, adequate humidity, presence of shade, adequate space within the hive, variable underfoot substrate and terrain. Good location, orientation, and disposition. Painting hives in colors and shapes. Adequate ventilation during transport and when stationary; correct wintering.		→		
DOMAIN 3 Health Challenges: Acute or chronic injury, poor health, poor fitness (e.g., queen quality, drone/queen fertility, productivity), and weakness (e.g., flight activity, colony). Opportunities: injury and disease-free, robust good health, good physical fitness.		→		
DOMAIN 4 Behavior Challenges: Limited positive interactions and behavior (e.g., restriction of natural foraging and flights, wax building, defending, fanning, egg laying, mating); lack of enrichment. Opportunities: Ability to express natural behaviors (e.g., foraging, swarming, flying, building wax, defending, ventilating, laying eggs, mating) and to interact within a balanced social structure.		→		

Table 3. Honey Bee Welfare practices (HBWPs), an overview of the domain distribution.

Honey Bee Welfare Category	Number of Honey Bee Welfare Practices Identified
Nutrition/Hydration (N)	40
Environment (E)	90
Health (H)	220
Behavior (B)	50
Mental state (M)	243

4. Discussion

The Five Domains Model, originally developed for vertebrates [34], has been adapted in the present work to the managed honey bees (Table 2).

Honey Bee (*Apis mellifera*) Welfare (HBW) includes the adoption of proper practices, named Honey Bee Welfare Practices (HBWPs), by the beekeeper. Starting from GBPs and BMBs already identified by in the EU project BPRACTICES, under the One Health approach [1,17,32,35–40], the proposed model evaluates both classic and emerging threats to honey bees, considering their belonging to the different welfare domains and their effects on small and large scales during stationary and migratory beekeeping practices.

The adoption of the Five Domains Model for honey bee welfare introduces a novel framework that extends beyond traditional beekeeping practices. This offers a more holistic

perspective by addressing both the physiological and psychological needs of honey bees, while emphasizing not only the single bee, but even the superorganism response as the primary focus to which beekeeping practices should be adapted. Through the application of the One Welfare framework and the Five Domains Model, HBWPs encompassed all aspects of managed bee life. This includes the health of the bees (by monitoring their health, preventing diseases, and ensuring responsible use of medications) along with their emotional well-being, which acknowledges the importance of honey bees' mental states for optimal welfare (by minimizing negative emotions consequential to negative conditions of living and favoring positive emotions, such as contempt or calmness, with environmental enrichments). Environmental impact is also thoroughly considered, considering factors such as pollution, location, exposition, available space, food and water resources and stores (based on colony size), predators, and interactions with other animals and humans.

This approach encompasses previously underexplored aspects such as the bees' mental state, their sufferance and their natural behaviors, acknowledging their importance in promoting not only the well-being of the colonies but also the sustainability of apiculture. Compared to those already considered by the B-PRACTICES project within the One-Health approach, the newly introduced welfare practices (28 in total) place special emphasis on honey bee physiology, behavior, and suffering. These practices aim to better recognize what is rewarding for honey bees, with the key objectives including alignment with the natural behaviors of *Apis mellifera*, promotion of gentle beekeeping, a reduction in unnecessary stress and suffering, and provision of environmental enrichment to enhance adaptability and choice.

For example, we discouraged the use of invasive techniques, such as queen artificial insemination and queen marking, as these practices strongly conflict with the bees' natural behavioral expression and cause unnecessary suffering. In addition, by promoting the use of locally adapted bee populations and non-invasive management practices, we aim to preserve the genetic integrity and natural behavior of pure honeybee subspecies or races, ensuring their resilience and sustainability over time. Moreover, when managing brood interruption, different beekeeping techniques can be compared, such as using trapped comb versus queen caging. Both techniques are effective in protecting bee health. However, in considering their impact on honey bee welfare, the method that allows the queen more freedom to exhibit her natural behavior should be favored. Similarly, additional behavioral considerations should be considered when evaluating practices such as drone brood removal, which is not permitted for bee welfare but is considered a good biosecurity measure against *Varroa destructor*. The use of local bee populations, which is requested for bee welfare to ensure autochthony, should also be prioritized as best as possible considering factors such as productivity, costs for the beekeeper, the difficulty to avoid hybrids, and honey production. In terms of environmental enrichment, we recommended the introduction of beehives in highly biodiverse areas with great numbers of melliferous and nectareous plants or selecting diverse foraging regions avoiding monocultures, areas with conventional agriculture density, or polluted environments in general, and we considered a balanced and rational use of supplementary feeding to be extremely important, advising its use only when necessary.

Additionally, we highlighted the need to prevent unnecessary bee mortality through more gentle management practices, such as using latex gloves to improve the beekeeper's tactile sensitivity and avoid accidental bee crushing, applying bee culling with CO₂ before hive destruction, and recognizing bee mental states by avoiding hive inspections when bees are extremely aggressive or irritable.

Furthermore, adopting this model and pursuing a positive welfare state could improve resilience to emerging threats, such as climate change, habitat loss, and pesticide exposure, which are increasingly affecting honey bee populations worldwide.

The integration of these additional practices into beekeeping management also has the potential to foster greater public awareness and support for honey bee conservation efforts.

Future research should aim on developing valid, reliable, and feasible indicators for assessing the effectiveness of these practices, enabling the evaluation of welfare conditions once they are implemented in the field. Such indicators could provide valuable data to further refine the HBWPs and help bridge any gaps between scientific recommendations and practical application in diverse environmental and cultural contexts. Continuous monitoring and feedback loops between researchers and practitioners will be essential to adapt these practices dynamically as new challenges arise.

Further validation, harmonization and scoring of HBWPs across different geographic contexts and types of beekeeping will require expert knowledge elicitation [41–48]. To ensure this process is multidisciplinary, and produces transparent and unbiased measures [26], it should involve not only beekeepers, apiculture experts, and beekeepers' associations but also specialists from related fields of welfare science, such as veterinarians, biologists, ecologists, ethologists, and legislators.

Now that HBWPs for managed *Apis mellifera* are established, valuable tools can be developed to further enhance beekeeping management. These tools could include the creation of specific manuals, guidelines, and practical instructions for beekeepers and policymakers, as well as the development and the improvement of dedicated checklists for audits, official inspections, and self-assessment tools [6,7,42,48–50]. All of these resources can be revised and refined based on the HBWPs already identified with the present paper.

Finally, to encourage adherence to these practices and promote compliance among beekeepers, dedicated labelling and marks, such as complementary or integrated organic production labels, can be introduced to certify good will, proper management and boost farmers' income [51–55]. To encourage adherence to these practices and promote compliance among beekeepers, specific marks and labels, such as certification programs, could be introduced. Such certification would not only offer specific incentives for farmers [3,13,53,56–58], but also enhance consumer trust in the sustainability and welfare standards of beekeeping practices [51,53–55]. There are already established quality certification programs in animal husbandry that ensure animal welfare, and in Italy, the Classy Farm [46] integrated system is applying a similar approach to beekeeping, ensuring the welfare of honeybees within the broader framework of sustainable farming practices [45].

As consumers become more informed about the welfare standards behind hive products, their demand for ethically produced honey and other by-products is likely to increase, which could drive market preferences toward more sustainable beekeeping practices. In turn, this could incentive more beekeepers to adopt HBWPs, thereby creating a positive feedback loop that benefits both the bees, beekeepers, consumers, and the broader ecosystem services they support.

This approach to including welfare considerations in beekeeping represents a transformative step toward sustainable and modern apiculture. The new Honey Bee Welfare Practices prompt to intervene on long-term effects that proper beekeeping management have on ecosystems and biodiversity. Following a positive approach, they seek to minimize environmental impact and enrich bee life, offering opportunities for positive experiences while still reducing and controlling negative stressors. Moreover, they allow bees to choose their optimal conditions.

The holistic perspective framing these practices advocates for gentle beekeeping and recognizes the interconnectedness of humans, animals, and their environments to achieve optimal welfare conditions. As we highlighted with the HBWPs list, beekeepers can be guided to carry out these practices through specific training programs, peer discussions among beekeepers, collaboration with scientific authorities, and input from veterinary professionals.

Performing the above-mentioned new practices together with the previous one already identified, will empower both bees and beekeepers to make informed decisions regarding welfare options. This approach emphasizes that improving animal welfare directly benefits human welfare, and vice versa, and underscores the need for coordinated actions between veterinary and other services. Moreover, welfare considerations for honey bees highlight environmental protection as a fundamental step in safeguarding the well-being of both

humans and animals [30]. An important challenge moving forward will be the development of practical strategies for implementing these practices on a large scale. This will require collaboration between researchers, practitioners, and policymakers to ensure that these practices are effectively integrated into beekeeping management and adapted to different regional contexts such as professional, and hobbyist beekeeping, organic beekeeping, propolis production, queen breeding, transport, and bee protection efforts. To achieve this, future research should involve the collaboration of beekeepers, ecologists, veterinarians, and policymakers, ensuring that HBWPs are validated, harmonized, and scored according to regional variations in beekeeping practices and environmental conditions.

HBWPs should be evaluated across diverse beekeeping contexts, engaging a wide range of stakeholders, and developing tools such as manuals and guidelines to support their effective implementation.

By evolving beyond a sole focus on production and adopting a multidisciplinary and comprehensive strategy, beekeeping practices can now aim for more resilient hives and thriving colonies. This shift aligns with the One Welfare concept, as it benefits not only the honey bees but also supports beekeepers and promotes environmental sustainability toward a modern concept of apiculture [1,8,23,25,27,29–31].

In conclusion, the HBWP approach offers a comprehensive framework for improving honey bee welfare by integrating scientifically validated practices into daily beekeeping operations. The adoption of HBWPs is particularly important for beekeepers, veterinarians, policymakers, and researchers, as it provides clear and actionable guidance for managing apiaries in ways that prioritize honey bee health, behavior, and overall well-being. Furthermore, the development of tools such as checklists, guidelines, and manuals can facilitate the assessment and implementation of these practices, enabling stakeholders to align farm management strategies with the HBWPs. This approach not only enhances the sustainability of apiculture but also strengthens its role in supporting broader environmental and societal goals.

Author Contributions: Conceptualization, G.F. and E.G.; writing—original draft preparation, E.G.; writing—review and editing, G.F., E.G., V.L., C.R., C.P., M.P. and M.B.; visualization, G.F. and E.G.; supervision, S.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received external funding from the Italian Ministry of Health under the project Valutazione del benessere in *Apis mellifera* e messa a punto di protocolli operativi in relazione alle misure di biosicurezza e di contesto ambientale (BEEWELL), project ID LT 08/22 RC.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data supporting the results reported in this study are available upon request from the corresponding author.

Acknowledgments: We would like to acknowledge Andrea Gyorffy, Alessandra De Carolis, Marcella Milito, and Lauriane Mariame for their invaluable help and support during the preparation of this work.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Honey bee welfare practices (HBWPs) for sustainable beekeeping organized according to the honey bee welfare domain.

Heading	Honey Bee Welfare Practice	Honey Bee Welfare Domain
1. General Apiary Management Transportation	1. Comply with legal obligations concerning restrictions on animal movements in the case of notifiable diseases	H/M
	2. Transport/move only healthy colonies	H/M
	3. Transport hives avoiding the warmer hours of the day, providing adequate openings for air ventilation in the hives	E/H/B/M
	4. During transport, ensure that bees are exposed to minimal mechanical stress by scheduling stopovers to allow rest and recover	H/E/M
1. General Apiary Management Hygiene	5. Respect hygiene rules (e.g., periodically clean suits, gloves)	H/E/M
	6. Practice good hygiene when dealing with dead colonies (combs, food stores, boxes, etc.)	H/E
	7. Disinfect levers and other potentially contaminated equipment (e.g., gloves) after inspection of hives affected by transmissible diseases	H/E/M
	8. Do not place honey supers directly on the ground (avoid contamination with <i>Clostridium Botulinum</i>)	H/M
	9. Avoid contact with dust during the transport of the supers from the apiary to honey use	H/M
	10. Do not place beehives directly on the ground	H/E/M
	11. Use disposable gloves when managing diseased hives	H/M
1. General Apiary Management Bee health	12. For nuclei use only bees and brood combs from healthy colonies	H/M
	13. Balance colony strength among colonies, transferring frames only in the case of healthy hives	H/B/M
	14. Buy new bee colonies only after thorough inspection for bee diseases, preferably with a health certificate from a veterinarian	H/M
	15. Keep only healthy strong colonies in the apiary	H/M
	16. Avoid placing apiary in areas contaminated with pollutants that are not harmful to bees but pose risks to human health (e.g., heavy metals, PFAS, HPA, PAHs) to place apiaries	N/H/E/M
	17. Do not imbalance the proportion between nurse bees and brood while equalizing the hives; preferably use combs with hatching bees to fortify weak colonies	E/N/B/M
	18. Prefer queens that are more resistant to disease and adapted to local climatic conditions	H/E/N/M
	19. Keep newly introduced colonies separate from the existing stock for an appropriate period (at least one month) to monitor them against diseases to prevent transmissions	E/N/M
	20. Avoid, as far as possible, the introduction of swarms of unknown origin, or colonies or queens from other apiaries	H/M
	21. Keep purchased or weak colonies in a quarantine apiary	H/M

Table A1. Cont.

Heading	Honey Bee Welfare Practice	Honey Bee Welfare Domain
1. General Apiary Management Apiary management	22. Evaluate the melliferous and pollen capacity of the area and the availability of water resources	N/E/M
	23. Do not have beekeeping material abandoned in the apiary	H/E/M
	24. Keep a good balance between the number of hives and the amount of melliferous plants/pollen sources in the area where the apiary is located	N/E/M
	25. Avoid windy areas when placing apiaries	H/E/M
	26. Adjust the amount of hives in the apiary according to season, pollen, nectar, honey dew resources	N/E/M
	27. Place apiaries on a firm area	H/E/M
	28. Prevent drift occurrence: avoid keeping too many colonies in a single row	H/E/M
	29. Avoid having broken hives with openings or poorly maintained hives, to prevent robbing	H/E/M
	30. Locate the hive in a biodiverse area with a variety of melliferous and nectarous plants, as well as bushes that provide natural foraging and swarming opportunities for honey bees	B/N/H/E/M
	31. Locate the hive avoiding light pollution and excessive vibrations	E/H/N/M
	32. Locate the hives avoiding excessive chemical pollution (PPPs)	E/H/N/M
	33. Confine the queen in a way that allows her to move freely and lay eggs	B/M
	34. Respect the natural bee space between combs and remove any abnormal comb constructions	B/E/M
	35. Breed your own autochthonous, locally adapted queens	B/M
	36. Do not perform artificial insemination on the queen bee	B/M
	37. Do not perform genetic selection of the honey bees	
	38. Avoid moving hives unless necessary	B/E/M
	39. Avoid rearranging the order of combs unless necessary	B/E/M
	40. Prioritize gentle beekeeping practices during inspections preventing unnecessary suffering (e.g., by avoiding abrupt or sudden movements, using well-fitted latex gloves, lifting, or moving combs/frames carefully, avoiding bee crushing when closing the hive top, and using the smoker properly)	H/B/M
	41. Communicate with other stakeholders (e.g., beekeepers, farmers, advisors, veterinarians) in the area to coordinate actions for managing foraging resources	E/N/H/M
	42. Communicate with other stakeholders (e.g., beekeepers, farmers, advisors, veterinarians) in the area to coordinate actions preventing and controlling diseases (such as varroosis), and minimizing the risk of intoxication by PPPs	H/E/M
	43. Listen the noise coming from the hive before opening the hive	B/M
	44. Adopt effective techniques to control honey bee predators (such as ants, wasps, bee-eaters, rats, and bears)	E/B/N/M

Table A1. Cont.

Heading	Honey Bee Welfare Practice	Honey Bee Welfare Domain
1. General Apiary Management Wintering	45. Before winter, reduce the empty space in the hive	E/H/M
	46. Wintering: reduce the size of the hive entrance	E/H/M
	47. Wintering: perform beehive box maintenance (replacing parts or painting; verify the integrity of hive boxes, if needed)	E/H/M
	48. Wintering: verify the external position of the frames with stores in the hive	N/E/H/M
	49. Wintering: reduce the number of frames in the hive box	E/H/M
	50. Wintering: insert a divider board to reduce the volume for the hive nest	E/H/M
	51. Wintering: wrap the hive in black tar paper, if needed	E/H/M
	52. Ensure that honey bees are housed under optimal physiological conditions, including temperature and humidity control	E/H/B/M
1. General Apiary Management Human health	53. Have the support of an expert (e.g., veterinarian, technician) to provide assistance in case of need	H/M
	54. Use personal protective clothing and equipment when visiting honey bee colonies	B/H/M
1. General Apiary Management Colony management	55. Practice hive management according to region, season, strength of colony	H/N/B/E/M
	56. Replace the queens at least every two or three years except for those of high genetic value or for HBW reasons	H/B/M
	57. Do not replace the queens	
	58. Prevent swarming by insertion of new wax foundations	B/H/M
	59. Prevent swarming by colony splitting	B/H/M
	60. Comply with the planned schedule for beehive inspections	B/H/M
	61. Prevent swarming by placing of supers	B/H/M
	62. Prevent swarming by taking off the entrance reducer	B/H/M
	63. Prevent swarming by adopting genetic selection of the queens	B/H/M
	64. Prevent swarming by insertion of drawn combs	B/H/M
	65. Prevent swarming by removal of beehive's bottom board	B/H/M
	66. Mark the queen according to the date of birth	B/H/M
	67. Explore alternative methods for identifying the queen without marking her with metal disks or painting her thorax	H/B/M
	68. Orientate hive entrance so that the sun can reach the bees in the early morning hours	B/E/M
	69. Use a queen excluder	B/E
	70. Prevent drift occurrence: paint/draw numbers or identification signs on the front and entrance of the hive	H/B/E/M

Table A1. Cont.

Heading	Honey Bee Welfare Practice	Honey Bee Welfare Domain
1. General Apiary Management Colony management	71. Indicate the age of the combs on the top bar of the frame (e.g., the year of placement of the frame with foundation)	H/E/M
	72. Prevent swarming by removal of the beehive's bottom board	H/B/E/M
	73. Provide adequate openings in the hive for air circulation, if needed	E/H/B/M
	74. Reduce the opening of the hive entrance during robbing and cold periods and increase the opening of the hive entrance during the hot season	E/H/B/M
	75. Do not perform drone brood removal	H/B/M
	76. Encourage the natural construction of wax combs in the spring	B/E/M
	77. If bees show signs of agitation, restlessness, or aggression, wait until they have calmed down before continuing with inspections	B/H/M
	78. Prefer to place apiaries at a lower height than the foraging area, allowing foragers carrying nectar and pollen to return to their hive without fatigue	E/M
	79. Do not open the hive at night or when it is rainy or windy	B/H/E/M
	80. Monitor honey bee behaviors, including flight activity, noise levels, aggression, calmness, and other emotional states	B/H/M
2. Veterinary Medicines	81. Maintain appropriate distances between different apiaries	E/H/N/B/M
	82. Locate the hives where other apiaries are sufficiently far to avoid spread of diseases	H/E/M
	83. Ensure proper hive density per area	E/H/N/B/M
	84. Use only veterinary medicines for honey bees registered in your country or medicines legally imported	H/M
	85. Use only pharmacological products registered for beekeeping use, follow the usage instructions, and record the treatments	H/M
	86. Observe the withdrawal period of veterinary products and ensure that products from treated hives are not used for human consumption until the withdrawal periods have elapsed	H/M
	87. If using instruments for the application (formic acid dispenser, sublimators for oxalic acid treatment), ensure that they are appropriate and correctly calibrated for the administration	H/M
	88. Respect the required storage conditions for veterinary medicines and feeds	H/M
	89. Use only veterinary medicines for honey bees registered in your country or medicines legally imported	H/M
	90. Ensure that all treatments or procedures are carried out correctly as described in the instructions (respecting dosage and method of application)	H/M
	91. Do not carry out illegal treatments	H/M
	92. Dispose of used instrument and devices in a biosecure manner	H/M

Table A1. Cont.

Heading	Honey Bee Welfare Practice	Honey Bee Welfare Domain
3. Disease Management	93. In the case of notifiable diseases follow the instructions from the veterinary regulations and competent authorities	H/M
	94. In the case of infectious diseases clean all beekeeping material between uses (e.g., hive bodies, hive bottom boards, feeders, hive tools)	H/M
	95. Clean or disinfect (in the case of infectious diseases) the hive box before installing new colonies	H/M
	96. Carry out thorough inspections for clinical signs of bee diseases and presence of the queen in spring	H/M
	97. Carry out thorough inspections for clinical signs of bee diseases and presence of the queen at the end of the beekeeping season	H/M
	98. Quickly remove beehives with dead colonies	H/M
	99. Take samples for laboratory analyses when sick or dead bees are found, if needed	H/M
	100. Clean equipment, scrape off wax and propolis, on a regular basis	H/M
	101. Remove and process wax of all combs from dead, affected colonies	H/M
	102. Record the health status of the colonies: diseased/infected colonies (dates, diagnoses, ID of colonies affected, treatments and results)	H/M
	103. Renew 30% of the hive combs every year	H/M
	104. Verify promptly any signs of disease, asking a veterinarian (or a specialist)	H/M
	105. Do not move frames or any kind of biological material (for example, to balance hives) from one hive to another if their health status is not well known	H/M
	106. Inspect diseased hives only after inspections of healthy hives are ended	H/M
	107. Select the best performing stocks of honey bees	H/M
	108. Burn dead colonies	H/M
	109. Remove queens from colonies with clinical history of AFB disease	H/M
	110. Remove queens from colonies with clinical history of EFB disease	H/M
	111. Try to select and breed colonies that are more disease tolerant/resistant	H/M
	112. Record the origin and use of all disinfectants and consumable items used, keep all the records relating to the cleaning and disinfection procedures used on equipment or honey house (including data sheets for each detergent or disinfectant used) as well as all the records showing that these procedures have been effectively implemented (task sheets, self-inspection checks on the effectiveness of the operations)	H/M
	113. Disinfect equipment (for example, with NaOH, hypochlorite) on a regular basis	H/M
	114. Carry out thorough inspections for clinical signs of bee diseases and presence of the queen before supering the hives	H/M
	115. When necessary, follow appropriate protocols to humanely euthanize the bees, minimizing their suffering	H/B/M

Table A1. Cont.

Heading	Honey Bee Welfare Practice	Honey Bee Welfare Domain
4. Hygiene	116. Torching (blue flame) used as a disinfection method for hives and beekeeping tools in the case of transmissible diseases	H/E/M
	117. Bleaching (soda, NaOH, etc.) used as a disinfection method for hives and beekeeping tools in the case of transmissible diseases	H/E/M
	118. Incineration of affected colony, if needed in the case of transmissible	H/E/M
	119. Always incinerate affected colony in the case of transmissible diseases	H/E/M
	120. Water under high pressure and heated (90 °C) used as a disinfection method for hives and beekeeping tools in the case of transmissible diseases	H/E/M
	121. Autoclaving used as a method of disinfection of hives and beekeeping tools in the case of transmissible diseases	H/E/M
	122. Gamma-irradiation as a method of disinfection of beekeeping tools in the case of transmissible diseases	H/E/M
5. Biosecurity Measures Varroosis	123. Treat varroosis always according to national legislation and registration	H/M
	124. Adopt/provide hives with screened bottom boards	H/E/M
	125. Nuclei and swarms should originate from colonies with no clinical signs of <i>Varroa</i> -related diseases (ABPV, DWV, IAPV, KBV, SBV, etc.)	H/M
	126. Treat according to an integrated pest management concept, taking <i>Varroa</i> thresholds into account	H/M
	127. Maintain the number of <i>Varroa</i> below the harmful threshold in each colony	H/M
	128. Adopt diagnostic tools for measuring <i>Varroa</i> infestation levels (for example, icing sugar method, CO ₂ test, mite fall) after treatments and during the year (for example, in spring at the beginning of the beekeeping season or before harvesting)	H/M
	129. Treat simultaneously all colonies of the apiary and those in the same area	H/E/M
	130. Prepare colonies (e.g., absence of brood) before treatment to obtain the highest possible efficacy, depending on type of treatment and product	H/M
	131. Monitor efficacy of acaricide treatments, verifying <i>Varroa</i> fall after treatment	H/M
	132. Have good knowledge of the clinical signs and of the transmission methods of varroosis and viruses	H/M
	133. Perform at least two treatments per year	H/M
	134. Rotate active principles of veterinary medicines to avoid <i>Varroa</i> resistance	H/M
	135. Check the health status of drones producing colonies, especially for viruses	H/M
	136. Preferably use medicines allowed in organic farming to control <i>Varroa</i>	H/M
	137. Administer <i>Varroacide</i> treatments using active ingredients that prioritize bee welfare, such as those with lower toxicity for honey bees	H/M

Table A1. Cont.

Heading	Honey Bee Welfare Practice	Honey Bee Welfare Domain
5. Biosecurity Measures Varroosis	138. Provide a sufficient number of healthy spare bee colonies at the right time depending on climate and vegetation conditions	H/M
	139. Try to select and breed colonies that are <i>Varroa</i> tolerant/resistant	H/M
	140. Treat nuclei and swarms (no brood) with oxalic or lactic acid	H/M
5. Biosecurity Measures American Foulbrood	141. Perform the ropiness test to confirm a clinical outbreak of AFB in the apiary	H/M
	142. Quickly manage affected hives	H/M
	143. Check for <i>P. larvae</i> in asymptomatic colonies by laboratory tests (e.g., stored honey in combs, hive debris) to control the disease. Take samples of colonies (hive debris/adult nurse bees/powder sugar/stores of honey in combs) in winter season to detect <i>P. larvae</i> (by PCR method or microbial isolation) to control disease	H/E/M
	144. Perform laboratory analysis (isolation and/or PCR) to confirm a clinical outbreak of AFB in the apiary	H/M
	145. Melt down the combs of all colonies (with and without clinical signs) in the affected apiary and process wax safely to control the disease	H/E/M
	146. Verify presence of AFB-typical scales (not removable, firmly adherent to the cell wall) to confirm a clinical outbreak of AFB	H/M
	147. Destroy only hives that show AFB clinical signs	H/M
	148. Disinfection/incineration of all beekeeping equipment (beehives, nucs, mating boxes, boards, frames, queen excluders, etc.) of symptomatic hives. Disinfect all beekeeping equipment of asymptomatic hives located in AFB outbreaks	H/E/M
	149. Make shook swarms of hives that show clinical signs of AFB	H/E/M
	150. Increase frequency of hive inspections in asymptomatic colonies (and in other apiaries of the same beekeeper) in cases with lab positivity for spores of <i>P. larvae</i> or in cases with clinical signs of the disease in other hives of the same apiary	H/M
5. Biosecurity Measures European Foulbrood	151. Apply an AFB-test (field kit) to confirm a clinical outbreak of AFB in apiary	H/M
	152. In the case of an AFB outbreak, make shook swarms of all colonies (with and without AFB signs)	H/B/M
	153. Use stamping out (destruction) of all colonies in the apiary (with and without AFB signs) only if eradication is achievable	H/M
	154. Manage affected hives quickly to control the disease	H/M
	155. Search for the presence of removable scales and yellow and contorted larvae to diagnose a suspicious EFB clinical outbreak	H/M
	156. Perform laboratory analysis (isolation and/or PCR) to confirm clinical suspicion of EFB	H/M
	157. Select queen breeders free of EFB	H/M
	158. Make a shook swarm of hives that show EFB clinical signs	H/B/M

Table A1. Cont.

Heading	Honey Bee Welfare Practice	Honey Bee Welfare Domain
5. Biosecurity Measures European Foulbrood	159. Disinfect/incinerate the contaminated beekeeping equipment (beehives, nucs, mating boxes, boards, frames, queen excluders, etc.) of EFB symptomatic colonies in the case of a clinical outbreak	H/E/M
	160. Increase hive inspections in symptomless colonies in cases of lab positivity for <i>M. plutonius</i> or in cases with clinical signs of the disease in other hives of the same apiary	H/E/M
	161. Destroy hives that show EFB clinical signs	H/E/M
	162. Take samples (hive debris/adult nurse bees/powder sugar/stores of honey in combs) from asymptomatic colonies for laboratory testing in winter or in the case of an outbreak, to detect presence of <i>M. plutonius</i> (by PCR method or microbial isolation)	H/M
	163. Apply an on-field EFB kit to confirm a clinical outbreak of EFB in symptomatic hives	H/M
	164. Make a partial (take off only brood combs, leaving store combs) shook swarm of colonies that show EFB clinical signs	H/B/M
	165. Disinfect/incinerate all beekeeping equipment (beehives, nuc boxes, mating boxes, boards, frames, queen excluders, etc.) of EFB asymptomatic colonies in the case of a clinical outbreak	H/E/M
	166. Be aware of the odor when opening the hive—typically a sour smell occurs in suspect cases of the clinical form of EFB	H/M
	167. Make a shook swarm of all colonies of the apiary (with and without EFB signs) in the case of an EFB outbreak, to achieve eradication	H/B/M
	168. Make a partial (take off only brood combs, leaving store combs) shook swarm of all colonies of the apiary (with and without EFB signs) to control the disease	H/B/M
5. Biosecurity Measures Nosemosis	169. Destroy affected colonies of the apiary to achieve eradication	H/M
	170. Do not reuse combs (empty or with stores of honey and/or pollen) originating from depopulated (few workers and the queen) or collapsed hives	H/E/M
	171. Prevent pollution of artificial water sources with feces or drowned or dead bees	H/N/M
	172. Select queen breeders from <i>Nosema</i> spp. free stocks	H/E/M
	173. Select and breed <i>Nosema</i> spp. resistant honey bees, if possible	H/M
	174. Remove combs with signs of dysentery	H/E/M
	175. Take samples of forager honey bees (or powder sugar or debris) early in autumn or spring to diagnose nosemosis (PCR and microscopic methods)	H/M
	176. Adopt appropriate pathogen (e.g., <i>V. destructor</i>) control, to ensure a proper balance (nurse–forager bees) in the composition of the bee colony	H/M
	177. Treat (if there are any registered/permitted products available in the country) the colony for <i>Nosema</i> spp. when percentages of infected bees are high (>40%)	H/M
	178. Strengthen and stimulate the colonies in autumn and spring with the administration of stimulant integrators or feed supplements	H/N/M

Table A1. Cont.

Heading	Honey Bee Welfare Practice	Honey Bee Welfare Domain
5. Biosecurity Measures Aethinosis (if SHB is present in the area)	179. Ensure that the bees cover all frames in the hive (no empty space)	H/N/M
	180. Do not leave outside beehives any frames, combs or other material that could be attractive and edible for <i>A. tumida</i>	H/N/M
	181. Carry out hive inspections periodically to detect and eliminate the SHB parasite (adults and larvae)	H/M
	182. Trace movement of hives meticulously (identify hives, dates of movements, exact position)	H/M
	183. Control transport conditions, adopting proper isolation of beekeeping equipment and avoiding spread of SHB during transport	H/E/M
	184. Store combs, in order to prevent survival of SHB eggs and larval development, in a cold chamber at a temperature below 10 °C	H/M
	185. Give artificial nutrition at low amounts each time so the bees can consume it in a short time (pollen/protein feed/supplements are a good substrate for SHB reproduction)	H/N/M
	186. Have only healthy, strong colonies in the apiary	H/M
	187. Trace movements of supers and wax meticulously	H/M
	188. Use traps to monitor and control SHB presence in the apiary	H/E/M
	189. Store combs, in order to prevent survival of SHB eggs and larval development, in a chamber at less than 34% relative humidity	H/M
	190. Have only young queens with hygienic behavior	H/B/M
	191. Use queen bee excluder in order to avoid the presence of brood in the supers	H/B/M
	192. Have good knowledge of morphology of SHB eggs, larvae and adults	H/M
5. Biosecurity Measures Aethinosis (if SHB is not present in the area)	193. Have good knowledge of hive inspection methods to detect SHB	H/M
	194. Do not leave outside beehives any frames, combs or other material that could be attractive and edible for <i>A. tumida</i>	H/E/M
	195. Have only healthy strong colonies in the apiary	H/M
	196. Have only young queens with hygienic behavior	H/B/M
	197. Do not transport live material at risk (hives, queens, nucs, etc.) from areas where SHB is present into the apiary	H/M
	198. Ensure that the bees cover all frames in the hive (no empty space)	H/E/M
	199. Do not transport material at risk (supers, wax, pollen, etc.) from areas where SHB is present into the apiary	H/M
	200. Adopt specific traps for quick visual detection of SHB	H/E/M
	201. Monitor periodically for the presence of SHB by sampling debris or honey	H/M
	202. Do not transport live material at risk (hives, queens, nucs, etc.) from areas where SHB could be present into the apiary	H/M

Table A1. Cont.

Heading	Honey Bee Welfare Practice	Honey Bee Welfare Domain
5. Biosecurity Measures Aethinosis (if SHB is not present in the area)	203. Do not transport material at risk (supers, wax, pollen, etc.) from areas where SHB could be present into the apiary	H/M
	204. Use queen bee excluder in order to avoid the presence of brood in the supers	H/E/M
6. Animal Feeding and Watering	205. Do not feed the bees with honey, pollen, or supplements, unless the absence of pathogens (spores of AFB, chalkbrood, <i>Nosema</i> , EFB, etc.) is certified	H/N/M
	206. Provide artificial feeding, supplements, and water during times of shortage or anytime is needed, but avoid it when not necessary	N/M
	207. Wintering: verify that there is a sufficient amount of stores in the hive	N/M
	208. Provide nucleus and swarms with adequate food supply when needed	N/M
	209. Ensure the bees have access to safe water sources	N/H/E/M
	210. Do not feed bees openly in the field to prevent robbing and spread of diseases	N/H/E/M
	211. During transport provide adequate watering if needed	N/H/E/M
	212. Keep records of veterinary medicine treatments	H/M
	213. Registration of the beekeeper in the National Beekeeping Registry	H/M
	214. Record the exact position of the bee yards	N/H/E/M
7. Record Keeping	215. Identify with numbers/letters all the hives in each apiary	H/M
	216. Keep records of honey bee diseases and colony mortality or depopulation	H/M
	217. Set up a data-recording system that can be used to trace exactly which batches of commercial feed the colonies were fed with	N/H/M
	218. Keep all documents/certificates about the commercial feed used	N/H/M
	219. For each colony or group of colonies, require and keep all commercial and health documents, enabling their exact itinerary to be traced from their farm or establishment of origin to their final destination	H/M
	220. Record all reared colonies movements of incoming colonies traceable to their source	H/M
	221. Keep records of movements of hives, swarms, queen bees	H/M
	222. Record period of collection of hive products from each apiary	N/H/M
	223. Keep detailed records of the origin and use of all medicines, including batch numbers, dates of administration, doses, treated hives and withdrawal times; treated hives or apiaries should be clearly identified	H/M
	224. Keep all documents/certificates that indicate the raw materials used in feed manufactured by the beekeeper and given to the colonies	N/H/M
	225. Create a unique identification number for the apiary to easily trace the location of the hive (for stationary apiaries)	H/M

Table A1. Cont.

Heading	Honey Bee Welfare Practice	Honey Bee Welfare Domain
7. Record Keeping	226. Keep records of breeding activities (e.g., all breeding stock, queens' birth dates, their origin and arrival, the breeding dates, and outcomes in cases of instrumental insemination)	H/M
	227. Establish a data-recording system to ascertain the exact origin (batch) of bee products produced	H/M
	228. Keep all documents regarding self-checks and official controls on the proper management of the colonies and the sanitary and hygienic quality of the bee products	H/M
	229. Keep all documents proving that the bacteriological and physicochemical quality of the water used in the honey house, given to the colonies, or used in feed preparation meets official national standards for tap water	N/H/M
	230. Record the origin and use of all feeds used, keep all records of any feed manufacturing procedures and records for each batch of feed	N/H/M
	231. Keep a list of certified suppliers	N/H/E/M
	232. Record any other management changes that may occur	H/M
	233. Record any change in feeding	N/H/M
	234. Keep all laboratory reports, including bacteriological tests and sensitivity	H/M
	235. Keep reference samples (−20 °C) of all feeds administered to the bees	H/M
8. Training	236. Training/knowledge on honey bee diseases and clinical signs	H/M
	237. Follow a training program in beekeeping and honey bee diseases	H/M
	238. Record datasheets for each detergent/disinfectant used	H/M
	239. Record disinfection procedures used	H/M
	240. Record that disinfection procedures have been implemented	H/M
	241. Keep the documents certifying qualification and training of persons working with bee	M
	242. Attend personal training on beekeeping	H/M
	243. Attend personal training on One Welfare, with a focus on Honey Bee Welfare	B/E/H/N/M

N = nutrition; E = environment (inside and/or outside the hive); H = health; B = behavior; M = mental state. In bold is the main domain affected. Note: The listed Honey Bee Welfare Practices include Good Beekeeping Practices (from Rivera-Gomis et al. 2020, modified [47]), Biosecurity Measures in Beekeeping (from Pietropaoli et al., 2020 [19] modified), and Honey Bee Welfare Practices (Table 1 of the current paper).

References

1. Olate-Olave, V.R.; Verde, M.; Vallejos, L.; Perez Raymonda, L.; Cortese, M.C.; Doorn, M. Bee Health and Productivity in *Apis mellifera*, a Consequence of Multiple Factors. *Vet. Sci.* **2021**, *8*, 76. [[CrossRef](#)] [[PubMed](#)]
2. Garrido, C.; Nanetti, A. Welfare of Managed Honey Bees. In *The Welfare of Invertebrate Animals*; Carere, C., Mather, J., Eds.; Animal Welfare; Springer International Publishing: Cham, Switzerland, 2019; Volume 18, pp. 69–104, ISBN 978-3-030-13946-9.
3. Giovanetti, M.; Bortolotti, L. Pollinators and Policy: The Intersecting Path of Various Actors across an Evolving CAP. *Renew. Agric. Food Syst.* **2023**, *38*, e27. [[CrossRef](#)]
4. FAO. *Review of Existing Legislation to Protect Pollinators from Pesticides in Selected Countries*; FAO: Rome, Italy, 2022; ISBN 978-92-5-136265-5.

5. Moldoveanu, O.C.; Maggioni, M.; Dani, F.R. Environmental Ameliorations and Politics in Support of Pollinators. Experiences from Europe: A Review. *J. Environ. Manag.* **2024**, *362*, 121219. [\[CrossRef\]](#) [\[PubMed\]](#)
6. Keeling, L.J.; Marier, E.A.; Olmos Antillón, G.; Blokhuis, H.J.; Staaf Larsson, B.; Stuardo, L. A Global Study to Identify a Potential Basis for Policy Options When Integrating Animal Welfare into the UN Sustainable Development Goals. *Front. Anim. Sci.* **2022**, *3*, 974687. [\[CrossRef\]](#)
7. Keeling, L.; Tunón, H.; Olmos Antillón, G.; Berg, C.; Jones, M.; Stuardo, L.; Swanson, J.; Wallenbeck, A.; Winckler, C.; Blokhuis, H. Animal Welfare and the United Nations Sustainable Development Goals. *Front. Vet. Sci.* **2019**, *6*, 336. [\[CrossRef\]](#)
8. Brodschneider, R.; Gratzner, K. The FAO Guideline on Good Beekeeping Practices for Sustainable Apiculture. *Bee World* **2021**, *98*, 144. [\[CrossRef\]](#)
9. EFSA Scientific Committee; More, S.; Bampidis, V.; Benford, D.; Bragard, C.; Halldorsson, T.; Hernández-Jerez, A.; Bennekou, S.H.; Koutsoumanis, K.; Machera, K.; et al. A Systems-based Approach to the Environmental Risk Assessment of Multiple Stressors in Honey Bees. *EFSA* **2021**, *19*, e06607. [\[CrossRef\]](#)
10. Naug, D. Nutritional Stress Due to Habitat Loss May Explain Recent Honey bee Colony Collapses. *Biol. Conserv.* **2009**, *142*, 2369–2372. [\[CrossRef\]](#)
11. Vaudo, A.D.; Tooker, J.F.; Grozinger, C.M.; Patch, H.M. Bee Nutrition and Floral Resource Restoration. *Curr. Opin. Insect Sci.* **2015**, *10*, 133–141. [\[CrossRef\]](#)
12. De Jongh, E.J.; Harper, S.L.; Yamamoto, S.S.; Wright, C.J.; Wilkinson, C.W.; Ghosh, S.; Otto, S.J.G. One Health, One Hive: A Scoping Review of Honey Bees, Climate Change, Pollutants, and Antimicrobial Resistance. *PLoS ONE* **2022**, *17*, e0242393. [\[CrossRef\]](#)
13. Le Conte, Y.; Navajas, M. Climate Change: Impact on Honey Bee Populations and Diseases. *Rev. Sci. Tech.* **2008**, *27*, 485–497, 499–510. [\[CrossRef\]](#) [\[PubMed\]](#)
14. Sperandio, G.; Simonetto, A.; Carnesecchi, E.; Costa, C.; Hatjina, F.; Tosi, S.; Gilioli, G. Beekeeping and Honey Bee Colony Health: A Review and Conceptualization of Beekeeping Management Practices Implemented in Europe. *Sci. Total Environ.* **2019**, *696*, 133795. [\[CrossRef\]](#)
15. Scott, A.; Hassler, E.; Formato, G.; Rünzel, M.A.S.; Wilkes, J.; Hassan, A.; Cazier, J. Data Mining Hive Inspections: More Frequently Inspected Honey Bee Colonies Have Higher over-Winter Survival Rates. *J. Apic. Res.* **2023**, *62*, 983–991. [\[CrossRef\]](#)
16. Hristov, P.; Shumkova, R.; Palova, N.; Neov, B. Honey Bee Colony Losses: Why Are Honey Bees Disappearing? *Sociobiology* **2021**, *68*, e5851. [\[CrossRef\]](#)
17. Rivera-Gomis, J.; Bubnic, J.; Ribarits, A.; Moosbeckhofer, R.; Alber, O.; Kozmus, P.; Jannoni-Sebastianini, R.; Haefeker, W.; Köglberger, H.; Smadis Skerl, M.I.; et al. Good Farming Practices in Apiculture: -EN- -FR- Les Bonnes Pratiques Apicoles -ES- Buenas Prácticas de Explotación En La Apicultura. *Rev. Sci. Tech. OIE* **2020**, *38*, 879–890. [\[CrossRef\]](#)
18. Pietropaoli, M.; Ribarits, A.; Moosbeckhofer, R.; Köglberger, H.; Alber, O.; Gregorc, A.; Smadis Skerl, M.I.; Presern, J.; Bubnic, J.; Necati Muz, M.; et al. Biosecurity Measures in European Beekeeping: -EN- Biosecurity Measures in European Beekeeping -FR- Mesures de Biosécurité Dans l'apiculture Européenne -ES- Medidas de Seguridad Biológica En La Apicultura Europea. *Rev. Sci. Tech. OIE* **2020**, *39*, 725–735. [\[CrossRef\]](#)
19. Koralesky, K.E.; Rankin, J.M.; Fraser, D. The Everyday Work of One Welfare in Animal Sheltering and Protection. *Humanit. Soc. Sci. Commun.* **2022**, *9*, 430. [\[CrossRef\]](#)
20. Pinillos, R.G. *One Welfare: A Framework to Improve Animal Welfare and Human Well-Being*; CABI: Wallingford, UK; Boston, MA, USA, 2018; ISBN 978-1-78639-387-6.
21. Birch, J. The Search for Invertebrate Consciousness. *Nous* **2022**, *56*, 133–153. [\[CrossRef\]](#)
22. Andrews, K.; Birch, J.; Sebo, J.; Sims, T. Background to the New York Declaration on Animal Consciousness 2024. Available online: <https://sites.google.com/nyu.edu/nydeclaration/declaration> (accessed on 10 May 2024).
23. Hemsworth, P.; Mellor, D.; Cronin, G.; Tilbrook, A. Scientific Assessment of Animal Welfare. *N. Z. Vet. J.* **2015**, *63*, 24–30. [\[CrossRef\]](#)
24. Wilkins, C.L.; McGreevy, P.D.; Cosh, S.M.; Henshall, C.; Jones, B.; Lykins, A.D.; Billingsley, W. Introducing the Mellorater—The Five Domains Model in a Welfare Monitoring App for Animal Guardians. *Animals* **2024**, *14*, 2172. [\[CrossRef\]](#)
25. Grandin, T. Practical Application of the Five Domains Animal Welfare Framework for Supply Food Animal Chain Managers. *Animals* **2022**, *12*, 2831. [\[CrossRef\]](#) [\[PubMed\]](#)
26. Harvey, A.M.; Beausoleil, N.J.; Ramp, D.; Mellor, D.J. Mental Experiences in Wild Animals: Scientifically Validating Measurable Welfare Indicators in Free-Roaming Horses. *Animals* **2023**, *13*, 1507. [\[CrossRef\]](#) [\[PubMed\]](#)
27. Mellor, D.J.; Beausoleil, N.J.; Littlewood, K.E.; McLean, A.N.; McGreevy, P.D.; Jones, B.; Wilkins, C. The 2020 Five Domains Model: Including Human–Animal Interactions in Assessments of Animal Welfare. *Animals* **2020**, *10*, 1870. [\[CrossRef\]](#) [\[PubMed\]](#)
28. Mellor, D. Positive Animal Welfare States and Reference Standards for Welfare Assessment. *N. Z. Vet. J.* **2015**, *63*, 17–23. [\[CrossRef\]](#)
29. FAO. One Health, One Welfare. Available online: <http://www.fao.org/webcast/home/en/item/6273/icode/> (accessed on 1 August 2024).
30. Fraser, D. What Do We Mean by One Welfare? Available online: <https://www.woah.org/fr/animal-welfare-conf2016/PTT/2.1.%20Fraser%20D.pdf> (accessed on 20 September 2024).
31. Grandin, T. How to Improve Livestock Handling and Reduce Stress. In *Improving Animal Welfare: A Practical Approach*; Grandin, T., Ed.; CABI: Wallingford, UK, 2021; pp. 84–112. ISBN 978-1-78924-521-9.

32. Pietropaoli, M.; Skerl, M.S.; Cazier, J.; Riviere, M.-P.; Tiozzo, B.; Eggenhoffner, R.; Gregorc, A.; Haefeker, W.; Higes, M.; Ribarits, A.; et al. BPRRACTICES Project: Towards a Sustainable European Beekeeping. *Bee World* **2020**, *97*, 66–69. [\[CrossRef\]](#)
33. Formato, G.; Giannottu, E.; Roncoroni, C.; Lorenzi, V.; Brajon, G. *Apis mellifera* Welfare. Definition and Future Direction. *Front. Anim. Sci.* **2024**, *5*, 1486587. [\[CrossRef\]](#)
34. Mellor, D. Updating Animal Welfare Thinking: Moving beyond the “Five Freedoms” towards “A Life Worth Living”. *Animals* **2016**, *6*, 21. [\[CrossRef\]](#)
35. El Agrebi, N.; Steinhauer, N.; Tosi, S.; Leinartz, L.; De Graaf, D.C.; Saegerman, C. Risk and Protective Indicators of Beekeeping Management Practices. *Sci. Total Environ.* **2021**, *799*, 149381. [\[CrossRef\]](#)
36. El Agrebi, N.; Steinhauer, N.; Renault, V.; Graaf, D.C.; Saegerman, C. Beekeepers Perception of Risks Affecting Colony Loss: A Pilot Survey. *Transboundary Emerg. Dis.* **2022**, *69*, 579–590. [\[CrossRef\]](#)
37. Hristov, P.; Shumkova, R.; Palova, N.; Neov, B. Factors Associated with Honey Bee Colony Losses: A Mini-Review. *Vet. Sci.* **2020**, *7*, 166. [\[CrossRef\]](#)
38. Danieli, P.P.; Addeo, N.F.; Lazzari, F.; Manganello, F.; Bovera, F. Precision Beekeeping Systems: State of the Art, Pros and Cons, and Their Application as Tools for Advancing the Beekeeping Sector. *Animals* **2023**, *14*, 70. [\[CrossRef\]](#) [\[PubMed\]](#)
39. Gray, A.; Adjlane, N.; Arab, A.; Ballis, A.; Brusbardis, V.; Bugeja Douglas, A.; Cadahía, L.; Charrière, J.-D.; Chlebo, R.; Coffey, M.F.; et al. Honey Bee Colony Loss Rates in 37 Countries Using the COLOSS Survey for Winter 2019–2020: The Combined Effects of Operation Size, Migration and Queen Replacement. *J. Apic. Res.* **2023**, *62*, 204–210. [\[CrossRef\]](#)
40. Van Der Zee, R.; Gray, A.; Pisa, L.; De Rijk, T. An Observational Study of Honey Bee Colony Winter Losses and Their Association with *Varroa destructor*, Neonicotinoids and Other Risk Factors. *PLoS ONE* **2015**, *10*, e0131611. [\[CrossRef\]](#) [\[PubMed\]](#)
41. Hampton, J.O.; Hemsworth, L.M.; Hemsworth, P.H.; Hyndman, T.H.; Sandøe, P. Rethinking the Utility of the Five Domains Model. *Anim. Welf.* **2023**, *32*, e62. [\[CrossRef\]](#)
42. Montagnin, C.; Frasnelli, M.; Fusi, F.; Bonilauri, P.; Bertocchi, L.; Lorenzi, V. Preliminary Study on the Extension of the IT System ClassyFarm to the Apiary. *Acta IMEKO* **2024**, *13*, 1–5. [\[CrossRef\]](#)
43. Gilioli, G.; Sperandio, G.; Hatjina, F.; Simonetto, A. Towards the Development of an Index for the Holistic Assessment of the Health Status of a Honey Bee Colony. *Ecol. Indic.* **2019**, *101*, 341–347. [\[CrossRef\]](#)
44. Holighaus, L.; Zanon, T.; Kemper, N.; Gauly, M. First Evaluation of the Practicability of the CLASSYFARM Welfare Assessment Protocol in Italian Small-Scale Mountain Dairy Farms—A Case Study. *Ital. J. Anim. Sci.* **2023**, *22*, 995–1007. [\[CrossRef\]](#)
45. Moriconi, M.; Lorenzi, V.; Montagnin, C.; Forte, C.; Dondo, A.; Vevey, M.; Gaino, S.; Fusi, F.; Bergagna, S. Application of the ClassyFarm Checklist as Measurement Tool to Evaluate the Welfare of Cattle Kept in Tie-Stalls in Aosta Valley. *Acta IMEKO* **2024**, *13*, 1–5. [\[CrossRef\]](#)
46. Lorenzi, V.; Sgoifo Rossi, C.A.; Compiani, R.; Grossi, S.; Bolzoni, L.; Mazza, F.; Clemente, G.A.; Fusi, F.; Bertocchi, L. Using Expert Elicitation for Ranking Hazards, Promoters and Animal-Based Measures for on-Farm Welfare Assessment of Indoor Reared Beef Cattle: An Italian Experience. *Vet. Res. Commun.* **2023**, *47*, 141–158. [\[CrossRef\]](#)
47. Rioja-Lang, F.C.; Connor, M.; Bacon, H.J.; Lawrence, A.B.; Dwyer, C.M. Prioritization of Farm Animal Welfare Issues Using Expert Consensus. *Front. Vet. Sci.* **2020**, *6*, 495. [\[CrossRef\]](#)
48. Tuytens, F.A.M.; De Graaf, S.; Andreasen, S.N.; De Boyer Des Roches, A.; Van Eerdenburg, F.J.C.M.; Haskell, M.J.; Kirchner, M.K.; Mounier, L.; Kjosovski, M.; Bijttebier, J.; et al. Using Expert Elicitation to Abridge the Welfare Quality® Protocol for Monitoring the Most Adverse Dairy Cattle Welfare Impairments. *Front. Vet. Sci.* **2021**, *8*, 634470. [\[CrossRef\]](#) [\[PubMed\]](#)
49. Fernandes, J.N.; Hemsworth, P.H.; Coleman, G.J.; Tilbrook, A.J. Costs and Benefits of Improving Farm Animal Welfare. *Agriculture* **2021**, *11*, 104. [\[CrossRef\]](#)
50. Caporale, V.; Alessandrini, B.; Dalla Villa, P.; Del Papa, S. Global Perspectives on Animal Welfare: Europe. *Rev. Sci. Tech.* **2005**, *24*, 567–577. [\[CrossRef\]](#) [\[PubMed\]](#)
51. Heerwagen, L.R.; Mørkbak, M.R.; Denver, S.; Sandøe, P.; Christensen, T. The Role of Quality Labels in Market-Driven Animal Welfare. *J. Agric. Environ. Ethics* **2015**, *28*, 67–84. [\[CrossRef\]](#)
52. Alonso, M.E.; González-Montaña, J.R.; Lomillos, J.M. Consumers’ Concerns and Perceptions of Farm Animal Welfare. *Animals* **2020**, *10*, 385. [\[CrossRef\]](#)
53. Kehlbacher, A.; Bennett, R.; Balcombe, K. Measuring the Consumer Benefits of Improving Farm Animal Welfare to Inform Welfare Labelling. *Food Policy* **2012**, *37*, 627–633. [\[CrossRef\]](#)
54. Sørensen, J.T.; Schrader, L. Labelling as a Tool for Improving Animal Welfare—The Pig Case. *Agriculture* **2019**, *9*, 123. [\[CrossRef\]](#)
55. Ingenbleek, P.T.M.; Krampe, C. The End of Animal Welfare Labelling as We Know It? Persisting Problems at the Consumer Level and PLF-Based Solutions. *Front. Anim. Sci.* **2022**, *3*, 819893. [\[CrossRef\]](#)
56. La Prioritizzazione Delle Esigenze nel Piano Strategico Nazionale PAC 2023–2027. Available online: <https://www.reterurale.it/flex/cm/pages/ServeAttachment.php/L/IT/D/d%252F9%252Fc%252FD.07cf9fa428c1537fc6e5/P/BLOB:ID=24037/E/pdf> (accessed on 8 August 2024).

57. Animal Welfare Matters for the Common Agricultural Policy (CAP). Available online: https://eu-cap-network.ec.europa.eu/news/animal-welfare-matters-common-agricultural-policy-cap_en (accessed on 8 August 2024).
58. Tosini, G.P. European Common Agricultural Policy and Animal Welfare. *Riv. Dirit. Dell'economia Trasp. Dell' Ambiente* **2024**, *XXII*, 251–266.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.