

# Welfare of the honey bee (*Apis mellifera*): legal, biological and practical perspectives

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### Summary

Honey bee welfare is an emerging concept situated at the interface of veterinary science, apiculture, animal welfare science and environmental policy. The aim of this review was to discuss the legal status of the honey bee in Poland and the European Union, analyze the applicability of the Five Freedoms concept to honey bee colonies, and critically review the literature supplied for this study. Under the current legal framework, honey bees are not clearly protected by the general animal welfare provisions that apply to vertebrates or to farmed animals under Directive 98/58/EC, yet they are strongly present in animal health, biosecurity and disease-control regulations. The reviewed literature shows that honey bee welfare should be understood both at the individual and superorganism level and is shaped by multiple interacting factors, including queen quality, parasites and pathogens, nutrition, pesticide exposure, thermal conditions, migratory management and beekeeper practices. Contemporary approaches increasingly move beyond a purely productive or disease-centered perspective toward welfare-oriented frameworks such as the Five Domains model and One Welfare. In practice, safeguarding honey bee welfare requires biologically appropriate management, improvement of forage resources, disease prevention, careful monitoring and legal recognition of the species-specific needs of managed bees.

**Keywords:** honey bee welfare, *Apis mellifera*, beekeeping, Five Freedoms, law

Until quite recently, the welfare of the honey bee remained at the margins of classical veterinary considerations of animal welfare. This resulted from several factors: the invertebrate taxonomic status of bees, the difficulty of transferring to insects models developed for mammals and birds, and the dominance of a production-and-health-oriented approach in which apiary success was assessed mainly through survival, colony strength and honey yield. The available literature clearly shows, however, that such an approach is insufficient. Contemporary reflection on honey bee welfare encompasses not only health and productivity, but also the possibility of performing natural behaviors, access to diverse food resources, the quality of the living environment, the burden imposed by beekeeping procedures, and the impact of human practices on the functioning of the superorganism represented by the colony (11, 12, 23, 32).

The aim of this paper is threefold: first, to indicate the current place of the honey bee in Polish and European Union regulations relating to animal welfare; second, to critically relate the situation of this group of animals to the classical concept of the Five Freedoms;

and third, to present a review of the literature concerning the biological, environmental and organizational factors affecting honey bee welfare.

### Legal foundations of animal welfare in Poland and the European Union and the place of the honey bee

In EU law, the starting point for considerations of animal welfare is Article 13 of the Treaty on the Functioning of the European Union, according to which the Union and the Member States, when formulating and implementing certain policies, are to pay full regard to the welfare requirements of animals as sentient beings (1). This provision is of fundamental importance, but it is general in nature and does not in itself create detailed standards relating to honey bees.

The most important general EU act concerning animals kept for farming purposes, namely Council Directive 98/58/EC, lays down minimum standards for the protection of animals kept for farming purposes, but expressly does not apply to invertebrate animals (11). This means that the honey bee, although an animal kept by humans, has not been covered by a classical positive welfare regime analogous to that applicable

to many farmed vertebrates. Consequently, at EU level bees remain more a subject of animal health law, plant protection product law, agricultural law and environmental policy than of detailed welfare law *sensu stricto* (11, 13, 23).

The situation in Polish law is similar. The Act of 21 August 1997 on the Protection of Animals regulates the treatment of vertebrate animals and therefore does not cover invertebrates, including the honey bee, within its essential scope (1). For this reason, the basic concepts and mechanisms of the Act – such as humane treatment, the prohibition of cruelty, or detailed obligations toward farm animals – do not translate directly into the protection of honey bee welfare. This does not mean, however, that the honey bee remains outside the law. Its normative status is fragmented and derives from veterinary, sanitary, epizootic, agricultural and environmental regulations.

At EU level, an important role is played by Regulation (EU) 2016/429, the so-called Animal Health Law, which creates a framework for the prevention and control of transmissible animal diseases and also includes kept honey bees within the animal health system (28). From a welfare perspective, this is indirectly but genuinely important: colony health, biosecurity, trade in colonies and biological material, disease surveillance and movement requirements directly affect the reduction of suffering and losses in bee colonies. Similarly, in national law bees are addressed primarily through provisions concerning animal health and the control of infectious diseases, historically and currently especially in the context of American foulbrood and other diseases of official importance.

In practice, this means that the honey bee lies at the intersection of several normative orders. On the one hand, in Poland and in the EU it is not explicitly included in the classical catalogue of animals covered by detailed welfare protection. On the other hand, it is a species kept by humans, of very great economic and ecological importance, whose health, use and movement are subject to increasing regulation. Recent literature rightly points out that the current legal state does not fully reflect biological knowledge of the needs of the bee colony and does not keep pace with the development of insect welfare science (11, 23, 32). From a practical and axiological perspective, bees are therefore protected only fragmentarily: more through health protection and the limitation of environmental risk than through coherent, positive welfare standards.

### **Honey bee welfare and the concept of the Five Freedoms**

The classical concept of the Five Freedoms was formulated for animals kept by humans and for decades has constituted the foundation of thinking about welfare. In relation to the honey bee, however, it requires careful reinterpretation, because the object of assessment is not only the individual organism but also the

colonial superorganism. Despite these reservations, the Five Freedoms remain a useful heuristic tool.

Freedom from hunger and thirst in the case of bees means above all the colony's continuous access to appropriately diversified resources of nectar, pollen and water. It is not merely a matter of the absence of extreme energy deficiency, but also of meeting qualitative and mineral requirements necessary for brood rearing, the functioning of the hypopharyngeal glands, immunity and colony thermoregulation. The literature clearly indicates that poor forage conditions, monocultures, seasonal food gaps and improperly balanced supplementation may lead to malnutrition, weakened immunity and increased colony mortality (12, 22, 25, 32, 33).

Freedom from discomfort should, in bees, be related to the nest microclimate, living conditions and habitat quality. The bee colony regulates temperature and humidity within the nest with great precision, but this capacity has its limits. Inappropriate hive construction, insufficient space, excessive cooling or overheating, transport stress, unfavorable apiary location or lack of environmental shelter increase the physiological cost of maintaining homeostasis (12, 33). Studies on the influence of temperature on brood development confirm that thermal disturbances may result in developmental abnormalities and a deterioration in the quality of adult individuals (23, 32).

Freedom from pain, injury and disease appears to be the most obvious component of bee welfare. Parasites, pathogens, pesticide exposure and inadequate treatment are sources both of direct damage and of secondary collapse of colony function. *Varroa destructor*, viral infections, nosemosis, brood diseases and disturbances in queen quality are among the most important determinants of bee colony losses (6, 12, 15, 17, 18, 25, 27). In this area, traditional thinking about welfare most readily connects with veterinary practice.

Freedom to express natural behavior in the honey bee must include not only the behavior of individual workers, drones and queens, but also the emergent behavior of the whole colony. This includes free foraging flights, proper organization of oviposition and brood care, hygienic behavior, pheromonal communication, thermoregulation, nest defense, the possibility of swarming as an element of the species' biology, and the selection of food sources according to the colony's needs. Beekeeping practices aimed exclusively at production – for example, chronic suppression of swarming, excessive apiary density, overly frequent migrations or routine manipulations inconsistent with the biological rhythm of the colony – may limit the performance of these behaviors (12, 23, 32).

Freedom from fear and distress is probably the most difficult to capture in relation to insects, but it should not be dismissed a priori. New concepts of bee welfare are based on the precautionary principle and on the assumption that environmental and apiary stressors

may induce negative functional states both in individual organisms and at the level of the whole colony (11, 23). Such stressors include frequent opening of the nest, intensive transport, overheating, starvation, environmental toxins, chronic parasite burden and disruption of colony organization. In this sense, the Five Freedoms remain conceptually useful for bees, but they require supplementation by more modern models, especially the Five Domains and One Welfare, which better take into account the dynamics of the relationship between colony biology, the environment and human actions (11, 23).

### Main factors shaping honey bee welfare

**Definitions and models of bee welfare.** One of the most important points of reference remains the chapter by Garrido and Nanetti, who are among the pioneers of a systematic approach to the welfare of bees kept by humans (12). The authors propose that the welfare of the bee colony should be understood as maintaining the colony in as natural a state as possible while simultaneously limiting recognized threats. The strength of this approach lies in its consideration of the biology of the superorganism and its departure from the reductionist identification of welfare solely with productivity. An important development of this perspective was presented by Formato et al. (9), who incorporated bee welfare into the Five Domains model. The authors attempted to define welfare practices for honey bees and assigned them to the domains of nutrition/hydration, environment, health, behavior and mental state. This paper is of programmatic importance because, for the first time, it systematizes the beekeeper's actions as practices directed not only toward production and biosecurity, but also toward welfare understood more broadly. In the next step, Mortellaro et al. (23) situated these practices within the One Welfare concept, showing that welfare benefits or costs in beekeeping are simultaneously distributed across bees, the environment and humans.

In the Polish context, the popular-scientific article by Wilde and Roman (32) played an important ordering role. The authors indicate that the issue of bee welfare concerns not only the protection of pollinators as an element of nature, but also human responsibility for an animal that is used and dependent on apiary practices. This text has considerable synthetic value, although it does not yet build as developed a conceptual apparatus as the latest English-language publications.

**Colony health, colony losses and the multifactorial nature of threats.** Hristov et al. (17) systematize knowledge on colony losses by indicating their multifactorial aetiology. The authors emphasize the importance of interactions among parasites, pathogens, forage quality, pesticide exposure, climatic conditions and errors in apiary management. From a welfare point of view, it is important to move away from the search for a single dominant factor in favor of a model of

cumulative stressors. A similar conclusion emerges from the study by Olate-Olave et al. (25), based on apiary monitoring in Argentina. The authors demonstrated associations between productivity and colony condition and specific beekeeping practices such as queen replacement, equipment disinfection, the number of combs in the nest and the making of nucleus colonies. These findings are particularly valuable because they show that welfare and productivity are not mutually exclusive categories: biologically appropriate colony management may simultaneously improve economic performance. In the paper by Cilia and Nanetti (6), emphasis was placed on current health challenges and the development of diagnostic tools. The authors stress that bee health remains an area of dynamic change and that apiary management requires combining knowledge of diseases, ecology and field practice. For welfare, this means the need to monitor colonies and react quickly before superorganism decompensation occurs.

In recent years, an increase in bee colony losses has been observed in many regions of the world. One of the best-known phenomena is colony collapse disorder (CCD), consisting in the sudden disappearance of worker bees while the queen, food stores and brood remain in the hive (9, 19). From the perspective of bee biology and welfare, the colony functions as a superorganism in which the behavior of individual organisms is strictly linked to the functioning of the entire community, and physiological or environmental disturbances affecting single bees may lead to serious impairment of the whole swarm (8, 26). In this context, good welfare in bees may be defined, similarly to the welfare of other animals, as a state in which the organism is healthy, capable of expressing natural behavior and adapted to environmental conditions. In bees, welfare must be analyzed both at the level of individual organisms and at that of the entire colony. The bee colony is a highly organized social organism. Its functioning is based on a division of labor among the queen, workers and drones. Workers pass through successive life stages associated with specific tasks: from brood care, through comb building, to foraging (26).

Perry et al. (26) list the following as the most important elements of bee welfare:

- proper physiological functioning of individuals,
- stability of the colony's social structure,
- access to appropriate food resources,
- absence of excessive environmental stress,
- proper social and communicative behaviors.

### Main factors impairing bee welfare

Bee welfare is currently threatened by many interacting environmental, biological and anthropogenic factors.

One of the most important biological threats to bee health is the parasitic mite *Varroa destructor*, regarded as one of the most destructive bee parasites

worldwide (29). This parasite feeds on the fat body tissue of bees, weakens their immune system and transmits numerous viruses, including DWV, which causes wing deformities, shortened lifespan and loss of flight ability in bees (21). Other pathogens affecting colony condition include *Nosema ceranae* and chronic bee paralysis virus (CBPV), which lead to weakened colonies, increased worker mortality and disturbances in social behavior (10).

Bee exposure to pesticides is one of the most frequently analyzed factors associated with declines in colony numbers. Particular importance is attributed to neonicotinoid pesticides, which may induce so-called sublethal effects such as impaired spatial orientation, reduced learning ability, disrupted communication within the colony and diminished homing ability. These disturbances may lead to the disorientation of workers and their loss during foraging flights (14, 16).

Another important factor affecting bee welfare is the availability of diverse sources of pollen and nectar. Intensive agriculture and monocultures limit the diversity of forage plants. Nutritional deficiencies lead to weakened immunity, impaired larval development and reduced colony size. The consequence of these nutritional deficits may be increased susceptibility of bees to disease and greater colony losses (2, 19). These risk factors may be further intensified by climate change, which causes shifts in seasonality, destabilizes bee population dynamics and may lead to colony collapse (5, 20).

**The role of the queen and the reproductive quality of the colony.** Amiri et al. (4) presented one of the most important studies concerning the relationship between queen quality and colony health. The authors show that poor reproductive quality of the queen, reduced longevity, viral and parasitic diseases, and disturbances in pheromonal signaling translate directly into social cohesion within the colony, the brood pattern, the rate of renewal of the worker population and overwintering success. From a welfare perspective, the queen is not merely a production tool, but the central element organizing the functioning of the whole superorganism. The importance of queen quality is also confirmed by practical studies. Olate-Olave et al. (25) included queen replacement among the most important factors associated with colony productivity. Garrido and Nanetti (12), in turn, indicated that neglect in this area may lead to a cascade of disturbances: weakened brood production, reduced worker numbers, poorer colony defense and greater susceptibility to disease. In apiary practice, concern for bee welfare therefore also means selecting, inseminating, replacing and assessing queens according to biological criteria rather than merely commodity-oriented ones.

**Diseases, parasites and colony immunity.** The most important parasite affecting bee welfare remains *Varroa destructor*. Review and research papers consistently show that this mite acts not only as a direct

damaging factor but also as a vector or amplifier of viral infections, leading to decreased survival, impaired brood development and winter losses (6, 17, 25, 27). Ramos-Cuellar et al. (27) pointed out that colony resistance to viral infections and to varroosis depends on genotype, whereas climate alone does not explain the observed differences. This is practically important for breeding lines that are more resistant. Iorizzo et al. (18) discussed the potential of lactic acid bacteria as a tool supporting bee health and welfare. The authors emphasize the antimicrobial and immunomodulatory properties of these microorganisms, while at the same time noting that the use of probiotics should be evidence-based and cannot replace basic biosecurity measures. This is an example of an approach in which improving welfare consists in strengthening the biological resistance of the colony rather than relying solely on pharmacological intervention.

Mráz et al. (24) investigated the effect of artificial diets and temperature on the growth of *Ascosphaera apis*, the pathogen responsible for chalkbrood. The results of this study show how strongly environmental and thermal factors modulate disease threats. This opens a broader perspective: bee welfare depends not only on the presence or absence of a pathogen, but also on the ecological and microclimatic context that determines whether a pathogenic factor will express its pathogenicity.

In the study by Haran et al. (15), hygienic behavior was assessed in colonies of *Apis cerana indica*, indicating its value in the selection of more resistant colonies. Although this concerns a different subspecies or distinct managed taxon than the *Apis mellifera* predominant in Europe, the study reinforces the general conclusion that hygienic behaviors constitute a key component of welfare and the health resilience of the superorganism.

**Nutrition, forage resources and the environment.** Malnutrition and dietary monotony are identified in the literature as fundamental threats to welfare. Garrido and Nanetti (12) describe very convincingly that the bee colony needs not only energy, but also adequate pollen quality, water and mineral resources. Nutritional deficits affect the development of the hypopharyngeal glands, larval feeding, immunity and worker longevity. The authors also show that sugar feeding may be a measure that saves the colony during overwintering, but it is not a full-value equivalent of natural resources. McKinnon et al. (22) demonstrated the usefulness of precise monitoring of flight activity and pollen diversity for assessing colony condition during pollination. The value of this work for welfare issues lies in the combination of behavioral and environmental data. The poorer and less stable the forage base, the greater the risk of colony overload, weakened development and increased susceptibility to other stressors.

Gasparini et al. (13) presented the experience of a collaborative project aimed at monitoring and pre-

venting pesticide poisonings. The authors showed that contemporary bee welfare cannot be analyzed separately from the agricultural landscape and the practices of plant protection product use. Acute poisonings and sublethal effects of pesticides do not always lead to the immediate death of the whole colony, but they may disturb orientation, flight activity, social behaviors and reproduction, thus affecting welfare at the functional level.

Xu et al. (33) described the influence of elevated temperature during the early stage of capped brood on pupal development and appendage size in adult workers of *Apis cerana*. Although the study concerns an Asian species, its results confirm the general principle that heat stress during the developmental stage may leave a lasting morphological and functional mark. In the era of climate change, these conclusions are also becoming important for European beekeeping.

#### **Beekeeping practices, migration and monitoring.**

One of the most interesting problems is the effect of migratory beekeeping on bee welfare. Alger et al. (3) demonstrated that migratory beekeeping may increase the burden of pathogens and parasites on colonies and affect colony size. This does not mean that every migration is by definition contrary to welfare, but it does show the biological cost of transport, mixing of populations and production pressure. Beekeeping practices were discussed extensively by Formato et al. (11), who indicated a very broad catalogue of welfare practices: from apiary location, through hygiene and biosecurity, to limiting unnecessary manipulations and taking account of colony biology when planning procedures. Their proposal is valuable because it reverses the logic of thinking: instead of asking only how to maintain production despite stressors, it asks how to manage an apiary so that the management system itself does not generate unnecessary suffering and dysfunction. This approach is complemented by the work of Mortellaro et al. (23), in which these practices were also analyzed in terms of their effects on humans and the environment. The authors point out that welfare-oriented solutions are not always economically and temporally neutral, but in the longer perspective they may bring benefits in the form of more stable colonies, lower losses and greater social acceptance of beekeeping.

#### **Integrative directions: Five Domains and One Welfare**

The strongest trend present in the latest literature is the shift from the One Health approach to the broader One Welfare model. In practice, this means recognition that bee welfare is not merely a function of effective disease control, but the result of the relationships among colony biology, the beekeeper's actions, the agricultural landscape and social goals (11, 23). Such a model better explains why even a correct health intervention does not guarantee high welfare if the colony is chronically malnourished, overloaded by pollina-

tion work, exposed to toxins or kept under conditions that restrict natural behavior. It should be emphasized that the One Welfare model does not replace the Five Freedoms, but deepens them. It makes it possible to move from the mere elimination of negative states to the active creation of conditions conducive to the positive functioning of the bee colony. For beekeeping, this means shifting the emphasis from reaction to crisis toward designing environments and management practices that are compatible with the biological needs of the species (11, 12, 23).

Analysis of the literature leads to several conclusions. First, honey bee welfare is a real and scientifically useful category, although it requires moving away from the simple transfer of models developed for vertebrates. Here, the unit of assessment is not only the individual organism, but also the colony as a superorganism. Second, health and welfare are closely linked, but they are not identical concepts. A colony may show no obvious signs of disease and nevertheless function under conditions of chronic nutritional, environmental or organizational stress. Third, the quality of beekeeping practices proves to be as important a factor as parasites and pathogens. Finally, the current legal status in Poland and the EU remains inconsistent with the growing body of knowledge about the needs of bees kept by humans. In light of the available sources, the most justified approach seems to be to treat bee welfare as a multidimensional category encompassing colony health status, queen and brood quality, access to forage resources, the stability of the nest microclimate, the possibility of expressing natural behaviors, the limitation of stress caused by apiary procedures, and the relationship between the apiary and the agricultural landscape. Such an approach has significance not only theoretically: it may also provide the basis for building standards of good beekeeping practice, criteria for apiary audits, training for beekeepers and future legal recommendations.

#### **Conclusions**

At present, the honey bee is not clearly covered in Poland or under EU law by the classical, detailed welfare-law regime applicable to farmed vertebrates; its legal status derives primarily from general, health, veterinary and environmental provisions.

Further development of science and practice requires the elaboration of operational indicators of bee welfare and greater recognition of the biological needs of bee colonies in law, education and apiary management.

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