1

Pollinators, Food Security, and Climate Resilience

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Warming stripe and biodiversity stripe.[1]

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> *As we unravel the secrets of insects, we discover the threads that weave the tapestry of life on Earth. May Berenbaum*

The Role of Insects in Ecosystem Function and Nutrition

Given the interdependence of human, animal, plant, and environmental health, understanding the ecological role of insects is essential to any discussion of pollinator resilience and global health. Insects are critical to the maintenance of terrestrial and aquatic ecosystems, linking primary producers and decomposers with higher trophic levels. Thus, insects represent a biological bridge between ecosystem function and human/animal nutrition. Their contributions extend beyond pollination to include nutrient cycling, soil formation and fertility, and biological pest control processes essential to agricultural productivity and ecological stability (Losey and Vaughan 2006; Cardoso et al. 2020). The degradation or loss of these functions would cause widespread ecosystem imbalance and threaten global food systems. It is a critical time for veterinarians to join the efforts to save insect species, not only for ecosystems, but for human and animal survival.

Ecological Interdependence and Insect Decline

Recent evidence of global insect declines poses a multifaceted risk to ecological integrity and human well-being (Nath et al. 2022; Brunet and Fragoso 2024). Diminishing insect populations disrupt pollination networks, nutrient turnover, and the energy flow between trophic levels, threatening both natural and agricultural ecosystems (Goulson 2019; Sánchez-Bayo and Wyckhuys 2019). Global declines in insect populations have also affected vertebrate pollinators (birds, bats, amphibians, and reptiles) and threaten 40% of invertebrate pollinators, including wild bees and butterflies (IPBES 2024). Such disruptions could result in reduced crop diversity, impaired soil fertility, and

1 Hawkins, E. (2024) *Global warming stripes*. UK Met Office. Available at: https://showyourstripes.info (Accessed 13 Nov 2025). Licensed under CC BY 4.0. biodiversitystripes.info (2024) *Biodiversity stripes (Living Planet Index data)*. Available at https://biodiversity stripes.info (Accessed 13 Nov 2025). Licensed under CC BY-SA 4.0.

weakened forest resilience – outcomes that collectively undermine climate stability and food security. In every process of renewal, from decomposition to pollination, insects are indispensable partners in sustaining life.

Pollination, Climate Change, and Global Food Systems

Pollinators are indispensable to both biodiversity maintenance and food production. Approximately 90% of the world's flowering plant species depend, at least in part, on animal pollination for reproduction (Tong et al. 2023). These pollination services sustain the availability of fruits, vegetables, nuts, and seeds that supply essential calories, vitamins, minerals, and phytonutrients to human and animal diets (Chaplin-Kramer et al. 2014). By contrast, wind-pollinated cereals (wheat, corn, soybeans, rice, barley, and oats) provide calories and macronutrients but lack the full complement of micronutrients derived from insect-pollinated crops. Thus, insect pollination directly influences both the quantity and nutritional quality of the food supply serving as a biological bridge between ecosystem function and human/animal nutrition. The global decline of insect populations constitutes not only an ecological crisis but also a profound threat to food system resilience (Hallmann et al. 2017; Wagner et al. 2021; Cornelisse et al. 2025).

Although this book focuses on honey bees, it is important to recognize the global impact of climate change on the well-being of all living things. Honey bees, native bees, other managed bees, and all animal pollinators, vertebrate and invertebrate, are affected by environmental changes, including climate shifts, weather extremes, habitat loss, pests, and pesticide exposure. The social insects are more resilient to climate change because their colony behavior buffers against environmental fluctuations (Menzel and Feldmeyer 2021). A more recent long-term study of North American insect populations included aerial weather radar data and concluded that insect population fluctuations and density depended on climate drivers, particularly landscape temperatures (Tielens et al. 2025) (Figure 1.1).

Climate change is reshaping the phenology, forage availability, disease ecology, and management logistics of honey bee colonies across North America. Unfortunately, the continued rise in carbon emissions and greenhouse gas (GHG) concentrations are driving unprecedented global warming and widespread thermal stress across ecosystems. Since the Industrial Revolution (1800s), atmospheric CO_2 has climbed from ~280 ppm to more than 430 ppm, an increase of over 50% since pre-industrial times (NOAA 2025). Emission rates must be significantly reduced if we are to stay below the crucial threshold of 2 °C (and preferably 1.5 °C) established by scientists from 193 nations signing the Paris Agreement (https://www.un.org/en/climatechange/paris-agreement). This represented the threshold temperature increase identified to curb global warming and mitigate the most catastrophic consequences of extreme weather events for human, animal, and plant health. Continuing emissions of GHGs from human activities will cause more climate changes – the severity increasing with every ton emitted (IPCC 2023; NAS 2025).

Migratory bees travel across diverse biomes with varying nutritional resources and climatic conditions. As winters become increasingly erratic – short warm spells alternating

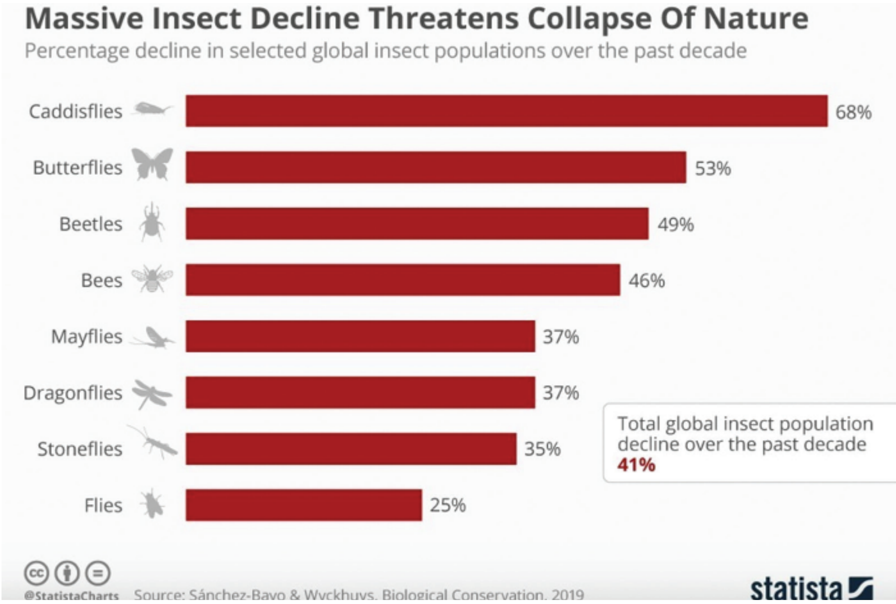

Figure 1.1 Massive insect decline threatens collapse of nature: percentage decline in selected global insect populations over the past decade. *Source*: Statista (2020). Massive insect decline threatens collapse of nature. Based on Sánchez-Bayo & Wyckhuys, Biological Conservation (2019). Licensed under CC BY-ND 4.0.

with intense cold, prolonged droughts followed by atmospheric river events (especially on the US west coast) and intense storms in the Midwest – commercial beekeepers are losing the expected seasonal predictability they have relied on in the past. The availability of nutritional resources across these multiple biomes is also less predictable. While cacti are more heat/drought resilient (their flowers tend to open at night), most flowering plants that produce nectar and pollen are much more vulnerable to high temperatures, especially during their reproductive phase, and this is particularly pronounced in insect-pollinated crops and wildflowers (McCombs et al. 2022; Walters et al. 2025).

Although not a new strategy, warehousing (or cold-storage) of commercial colonies is becoming increasingly common as a way to buffer hives from unpredictable external conditions, synchronize populations, and reduce bees' energy expenditure when forage is insufficient to prepare them for early-February almond pollination (DeGrandi-Hoffman et al. 2025) (Figures 1.2–1.4).

Figure 1.2 A century old hand-dug cellar near Arapahoe, WY, USA. This is an early example of a much-decayed storage cellar. Colonies of bees were hand carted into the cellar for winter. Ventilation pipes (no longer visible) brought in fresh air and a primitive chimney exhausted air for "circulation." Cellar dug by Lawrence George Krause. *Source*: Photo by John Miller.

Figure 1.3 The North Dakota campus with the indoor storage building in the background. *Source*: Photo by John Miller.

Figure 1.4 Colonies of bees stacked in preparation for overwintering in the indoor storage building. Modern ventilation ductwork is visible in the ceiling. Refrigerated air keeps colonies at 40 °F. Air handlers push fresh air into the building, exhausting higher-level CO_2 outdoors. *Source*: Photo by John Miller.

Climate change exerts complex interrelated effects on insect populations, influencing their distribution, phenology, physiology, behavior, and ecological interactions (Le Conte and Navajas 2008; Goulson et al. 2015; Potts et al. 2016). Altered temperature and precipitation patterns can disrupt flowering phenology, decouple pollinator plant interactions, disrupt insect development, and alter community structure. Consequently, climate-driven shifts can desynchronize pollinators from the flowering periods of their host plants, reduce reproductive success, and alter community composition (Memmott et al. 2007). Overall, climate change amplifies existing threats to insects, leading to detrimental cascading risks to ecosystem function and biodiversity.

Thermal Stress and Range Shifts

Many insects operate within narrow thermal limits; even small deviations from optimal temperature ranges can impair metabolic efficiency, reproduction, and survival. As mean global temperatures rise, numerous species are shifting their ranges poleward or to higher elevations in search of suitable microclimates (Kerr et al. 2015; Lin et al. 2018). While some adaptable generalists may persist, habitat specialists, particularly native bees and butterflies, are disproportionately at risk (Kudo and Cooper 2019). Such range contractions, or expansions, and local extinctions threaten pollination networks and the stability of both wild and agricultural plant communities.

Phenological Mismatches and Resource Decline

Phenology is nature's calendar, determining when plants bloom, when insects emerge, when birds migrate, when coat color and plumage change, and when animals reproduce. These seasonal rhythms are intricately tuned to temperature, photo period, and precipitation, ensuring that species interact at the right times for feeding, pollination, and reproduction. However, climate change is disrupting this delicate timing. Warmer temperatures and altered precipitation patterns are shifting the phenology of many species, often causing mismatches between plants and their pollinators. For example, flowers may bloom earlier in spring, before bees and other insects have emerged from overwintering. Such asynchrony can reduce pollination success, weaken food webs, and threaten crop yields that depend on these pollinators (Rafferty 2017; Wen et al. 2024).

Bees are especially vulnerable as their life cycles are closely tied to environmental cues. Earlier or prolonged warm periods can cause premature emergence, leading to starvation if nectar sources are not yet available. Conversely, extreme weather events such as late frosts, droughts, and heat waves can damage floral resources or disrupt nesting and foraging behavior. Over time, these phenological shifts can reduce insect biodiversity and colony health, compromising ecosystem resilience and food security (Goulson et al. 2015; Forrest 2016; Stemkovski et al. 2020) (Figure 1.5).

Climate change also amplifies other anthropogenic stressors such as pesticide exposure, habitat degradation/

Figure 1.5 Major threats to pollinators include climate change (heat stress, phenology shifts, forage disruption), habitat loss (urbanization, monocultures, reduced nesting sites), disease (viruses, parasites, and pathogens affecting colony survival), and pesticides (acute and sublethal impacts on navigation, immunity, and reproduction). *Source*: T.R. Kane.

loss, and pathogen transmission (Potts et al. 2016). Rising global temperatures, shifting precipitation patterns, and increased frequency of extreme weather events (droughts, floods, heat or cold waves, fires, and the resulting pollution) can weaken pollinators directly (Chen et al. 2025; Duque and Steffan-Dewenter 2024; Ryalls et al. 2022). Beyond these direct impacts, climate change also exacerbates indirect stressors, including pathogen proliferation and pesticide sensitivity, particularly when bees are already nutritionally or physiologically stressed. Global temperatures are reshaping the ecology of honey bee pathogens and parasites. Warmer conditions extend brood-rearing periods and increase colony activity, creating more opportunities for the transmission rates of pathogens such as European foulbrood (EFB) *Melissococcus plutonius*, the fungus *Vairimorpha* spp. (Nosemosis), and the parasite *Varroa destructor* carrying multiple viruses – all are significant contributors to honey bee colony losses (Table 1.1). The severe loss of colonies in 2006 and 2025 resulted from an amalgamation of stressors (see Chapter 16). These combined pressures, in which chronic environmental degradation interacts with acute climatic shocks, accelerate population declines across multiple taxa (Cardoso et al. 2020).

Simultaneously, climate-driven habitat alteration reduces the diversity and availability of floral resources, forcing pollinators to forage over larger distances and expend more energy. Habitat fragmentation also limits nesting and overwintering sites, further increasing vulnerability to disease and pesticide exposure. When combined, these pressures create synergistic effects, nutritional stress can weaken immune defenses, heightening susceptibility

Table 1.1 Influence of warming temperatures on major honey bee pathogens and parasites.

Pathogen/disease	Evidence for temperature link	Mechanistic/ecological notes	Key references
Varroa destructor + associated viruses (deformed wing virus, Israeli acute paralysis virus, black queen cell virus, etc.)	Warmer mean temperatures and longer warm seasons correlate with higher *Varroa* infestation probability and viral diversity, even when mite numbers are constant	Elevated temperatures extend brood rearing → more mite generations; increased forager activity → greater drift and mite exchange; deformed wing virus replicates efficiently at 34–35 °C but is suppressed at ≥37 °C	Smoliński et al. (2021), DeGrandi-Hoffman et al. (2025), Chen et al. (2025) McAfee et al. (2025), Abou-Shaara et al. (2024) See Chapter 16
Vairimorpha (*Nosema*) *ceranae*/*N. apis*	*N. ceranae* dominates in warm regions; infection intensity rises at 33–35 °C; spores lose viability near freezing	Climate warming favors thermotolerant *N. ceranae* over *N. apis*; mild winters enhance overwinter survival; hot, humid conditions promote spore germination	Retschnig et al. (2017), Chen et al. (2012) See Chapter 14
European foulbrood (*Melissococcus plutonius*)	Outbreak probability rises after rainy, nutrient-stress periods; *M. plutonius* grows optimally at 33–36 °C (typical brood temperature)	Ambient warming alone not a direct driver; heat stress and disrupted brood-nest thermoregulation favor opportunistic growth; nutritional stress remains dominant	McAfee et al. (2025), Fowler et al. (2025) See Chapter 12
American foulbrood (*Paenibacillus larvae*)	Spore germination and larval mortality accelerate at brood-typical and slightly elevated temperatures (34–37 °C)	*P. larvae* spores survive decades – heat mainly affects disease dynamics by altering colony defense and hygienic behavior; warmer brood areas can hasten bacterial growth if larval immunity is stressed	Alburaki and Garnery (2024), Rowland et al. (2021), Pijáček et al. (2021) See Chapter 12

to pathogens, while pesticide exposure may further impair detoxification and thermoregulation (Chapters 5 and 19).

Sustaining pollinator populations under changing climatic and environmental conditions requires multifaceted approaches that integrate ecological restoration, agricultural innovation, and health surveillance. These interventions must address both environmental and biological determinants of pollinator health, recognizing that ecosystem integrity, animal well-being, and human nutrition are interdependent (Zinsstag et al. 2011; Bonilla-Aldana et al. 2020).

Veterinary Medicine's Expanding Role in Global Health and Pollinator Health

The veterinary profession has a significant role in One Health and the impact of global climate change (Pappaioanou and Kane 2023). Veterinary medicine has historically focused public health efforts on the prevention and control of zoonotic diseases while less attention has been given to the impacts of climate change, environmental degradation, and declining insect populations, despite their direct links to food security, agricultural sustainability, and public health (VanEngelsdorp and Meixner 2010; Duncan et al. 2025). Encouragingly, this is changing. The World Veterinary Association (WVA 2022), the American Veterinary Medical Association (AVMA 2024), the Canadian Veterinary Medical Association (CVMA 2023), the Honey Bee Veterinary Consortium (HBVC 2026), and the American Medical Association (2022) have each issued statements acknowledging the public health implications of climate change. The HBVC, often working with entomologists near the veterinary colleges (Michigan State University's Pollinator Initiative is one example, https://pollinators.msu.edu/), have been instrumental in educating veterinarians and veterinary students through online learning, lectures, and hands-on laboratories. Increasingly, veterinary schools and professional conferences are incorporating honey bee and pollinator health into their curricula, often in collaboration with entomologists and apiarists. The HBVC's certification program in honey bee health (see Chapter 25) further formalizes this growing field.

Incoming veterinary students typically have a solid foundation in biology, chemistry, and mathematics. However, the complexity of pollinator health requires a broader education in ecology, entomology, and botany (Mayer 2021; Akello 2024). Traditional curricula emphasized insects primarily as vectors of disease, as parasites or pests of livestock and companion animals. While this perspective remains essential, it is incomplete as pollinators, particularly managed honey bees, other managed bees, and wild bees, are central to agriculture productivity and ecological resilience. Roughly one-third of global food crops require animal pollination (Klein et al. 2007; IPBES 2016). Expanding veterinary entomology to include the critical ecological roles of pollinators is a growing dimension of food animal medicine.

Currently, there are three international veterinary organizations dedicated to mitigating climate change and advancing sustainable environmental practices. They offer education and practical advice on mitigating/adapting to climate change for people, animals (large and small), veterinary practices, and our home and community ecosystem health:

- Veterinary Sustainable Alliance (https://veterinarysustainabilityalliance.org), a US/Canadian group founded in 2022
- Vet Sustain (https://vetsustain.org), a UK based organization founded in 2019
- Australian Veterinary Environmental Alliance (https://avea.org.au) previously known as Vets for Climate Action, an Australian group founded in 2019
- World Veterinary Environmental Alliance, (https://worldvetalliance.org), founded 2025

The inclusion of honey bees under the US Food and Drug Administration's Veterinary Feed Directive (VFD) in 2017 marked a turning point by formally integrating apiculture into veterinary oversight. Although historically focused on vertebrate livestock species, veterinary medicine now includes invertebrate health, particularly through honey bee medicine and apiculture programs (Pasho et al. 2021).

Veterinarians can support pollinator health through:

- Disease surveillance: Implementing standardized diagnostic protocols for bacterial, viral, and parasitic diseases.
- Biosecurity measures: Advising on hive management, disinfection, and movement control to prevent pathogen spread.
- Risk assessment: Evaluating pesticide exposure, forage quality, and environmental contaminants.
- Education and policy: Engaging producers, regulators, and the public in pollinator-friendly agricultural practices. All federal agencies are required to have climate action plans and for veterinarians, the US Department of Agriculture offers a plethora of information through Extension Services and websites (ClimateHubs.usda.gov; US Climate Resilience Toolkit, https://toolkit.climate.gov/hazard/shifting-species-habitats-and-ecosystems).
- Climate mitigation/adaptation and sustainable practices/policies.

Ecosystem-Based Mitigation and Adaptation

We are all living with climate change now – extreme weather events and dire environmental news occur every day and it is daunting. The environments where we live, work, and play form an ecosystem that we can influence on both macro and micro levels. Just as the human population benefits from a diverse array of talents and professions, the variety found in nature is essential for stability and resilience. This diversity enables recovery from disturbances of any kind. Each species has a niche that contributes to the web of interactions. The loss of any species component can have negative consequences, as we see with the loss of insects and the animals that prey on them.

Mitigation efforts aimed at slowing or reversing pollinator declines include habitat restoration, reduction of pesticide exposure, and enhancement of landscape diversity (Bishop et al. 2025). Establishing pollinator-friendly corridors and flowering strips increases forage availability and supports species with diverse phenological requirements (Hughes et al. 2018; Garibaldi et al. 2021). The Iowa Prairie Strip project (https://www.nrem.iastate.edu/research/STRIPS/what-strips-project) is an example of diversifying a large agricultural field with 10–40 m (30–120 ft) strips of native grasses and flowers to reduce soil erosion, improve water quality, and provide wildlife habitat. (Henning and Helmers 2024). Additionally, more than 13 years of research has demonstrated that converting 10% of a crop field to strategically placed prairie strips could result in the reduction of 95% of sediment, 90% of the phosphorus, and 84% of the nitrogen from overland flow of surface water. This conservation method has spread to multiple states (Figures 1.6 and 1.7).

Increasing biodiversity can also be tackled on a smaller scale at home, at veterinary practices, and in your communities. Removing lawns (or portions of), avoiding chemical pesticides and fertilizers, planting native plants with seasonal blooming schedules, and providing water sources for insects and birds is not only beautiful but your staff will appreciate your efforts, and you can educate your clients about the sustainable practices you have incorporated (Figure 1.8).

Mitigation and adaptation strategies aim to reduce drivers of insect declines while enhancing resilience to environmental change. Mitigation includes reducing harmful pesticide exposure through integrated pest management (IPM), protecting and restoring natural forage and nesting habitats, controlling pathogens and parasites, and promoting land management practices that buffer against climate extremes. Adaptation strategies involve supporting resilient pollinator populations through selective breeding, providing supplemental forage and water during periods of scarcity, designing hives and habitats to withstand environmental stressors, and implementing monitoring systems for timely interventions. Veterinarians play a key role in these efforts by assessing pollinator health, advising on management practices, and contributing to research and outreach

Figure 1.6 Prairie strips are a conservation practice that protects soil and water while providing habitat for wildlife. The strips (science-based trails of row crops integrated with prairie strips) are planted between rows of corn or soy beans to increase biodiversity and add habitat for pollinators. *Source*: Photo courtesy of Mower Soil & Water Conservation District.

(a) (b)

Figure 1.7 (a) Prairie strips in a cornfield. (b) Close up of a butterfly on *Echinacea purpurea* (purple coneflower, a common North American pollinator plant. *Source*: Photo courtesy of Mower Soil & Water Conservation District.

(a) (b)

Figure 1.8 (a) Pollinator garden at Chappelle Small Animal Hospital, Ft. Collins, CO. *Source*: Photo by Whitney Refvem. (b). Close up of pollinator garden at Chappelle Small Animal Hospital, Ft. Collins, CO. *Source*: Photo by Whitney Refvem.

initiatives that safeguard both pollinators and the ecosystems and agricultural systems they support.

Adopting agricultural integrated pest management and climate-smart agricultural practices minimizes chemical residues that impair insect health while maintaining crop productivity (Kremen et al. 2018). These ecosystem-based strategies enhance pollinator resilience and promote soil health, carbon sequestration, and biodiversity.

Integrating Policy, Research, and Collaboration for Pollinator Resilience

Cross-Sector Imperatives

Pollinator conservation depends on integrated action across agriculture, environmental management, and public health sectors. Coordinated policy, applied research, and professional collaboration are essential to address the intersecting pressures of habitat loss, pesticide exposure, climate change, and emerging diseases. Sustainable food systems and biodiversity require policies that prioritize habitat restoration, sustainable pesticide management, and diversified agricultural landscapes that enhance floral resources and ecosystem resilience under climate stress (Potts et al. 2016).

Collaborative Research and Data Integration

Continuous surveillance and data-sharing underpin evidence-based policy. Monitoring pollinator diseases, population trends, and environmental exposures provides the foundation for early-warning systems. Shared platforms linking apicultural inspection data, toxin screening, and climate variables enable predictive modeling and targeted interventions (FAO 2020; IPBES 2016). International frameworks such as the Food and Agriculture Organization of the United Nations (FAO) Global Action on Pollination Services for Sustainable Agriculture and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Pollination Assessment demonstrate how multi-stakeholder partnerships connect science with governance at both local and global scales.

Interdisciplinary Collaboration and Professional Roles

Integrating veterinary science, ecology, and agricultural management builds the adaptive capacity of pollination systems. Veterinarians contribute through surveillance, diagnostics, and policy advising, bridging field-level management with ecosystem-scale planning. Their involvement extends the One Health paradigm to include environmental determinants of nutrition and food production (Zinsstag et al. 2011). Collaborative education initiatives and professional organizations, including the AVMA, the CVMA, HBVC, HBHC's North American Bee Strategy, the Pollinator Partnership, Vet Sustain, and the Veterinary Sustainability Alliance, illustrate how coordinated professional efforts can translate scientific evidence into practical outcomes for pollinator health.

Frameworks for Research and Policy Integration

Resilient pollinator systems require integration within existing animal health and environmental programs. Expanding veterinary diagnostic networks to include pollinators enables early detection of pathogens, invasive species, and toxic exposures (Vanbergen et al. 2020). Standardized diagnostic and data-sharing protocols improve comparability and reproducibility across regions (Cameron et al. 2021). Targeted funding mechanisms such as joint agricultural and environmental research grants can incentivize interdisciplinary projects combining veterinary diagnostics, field ecology, and remote sensing technologies. Embedding pollinator protection within national food security and biodiversity strategies strengthens agricultural resilience and aligns conservation with climate adaptation and public health goals.

Governance and Future Directions

Policies that reward pollinator-friendly land use, support diversified cropping systems, and regulate pesticide application provide both ecological and economic benefits. Recognizing pollinators as bioindicators of environmental quality reinforces their value to sustainable agriculture and climate resilience. The future of pollinator health will depend on how effectively research, policy, and veterinary practice converge to sustain the biological foundations of global food security.

Summary

Pollinators form the biological foundation of global food production and ecosystems stability, and their decline is an urgent environmental indicator. This vulnerability of species loss also creates an opportunity to strengthen the connections among veterinary medicine, agriculture, ecology, and public health. As climate change reduces floral resource diversity, intensifies pathogen pressures, and disrupts phenology, pollinators provide early warning of the ecological pressures that ultimately affect human and animal nutrition and global food security (IPBES 2016). Their health is inseparable from ours.

As the chapters in this book show, veterinarians are qualified to contribute to pollinator resilience. Our expertise in diagnostics, surveillance, biosecurity, and population-level health enables early detection of diseases and bridges the gaps between ecological science and agricultural practice. By expanding existing herd-health monitoring principles to include honey bees and wild pollinators we could improve detection of pathogens, toxins, pests, invasives species, and climate-driven stressors (Cameron et al. 2021). We can bridge disciplines to collaborate on diagnostic standards and collect research data to facilitate coordinated regional responses when there is a threat to pollinators.

As you read the chapters in this book, you will understand the complex interactions among nutrition, pathogens, pests/pesticides, and climate variability. Targeted, cross-sector investments integrating veterinary medicine, landscape ecology, agronomy, and socioeconomics can accelerate the development of sustainable solutions. These solutions may include improved management, non-chemical disease control, habitat restoration, regenerative agriculture (diversified crop systems), and evidence-based policy frameworks. There are international initiatives we can learn from such as the IPBES Pollination Assessment and the Coalition of the Willing on Pollinators that illustrate the impact of coordinated scientific and policy action (FAO 2020).

Ultimately, protecting pollinators is not only a conservation mandate but the cornerstone of food-system resilience. Practice that supports pollinator health, pollinator-friendly land use, improving habitat quality, reducing pesticide exposure, and diversified agriculture landscapes strengthen ecosystem stability and actually increase productivity.

This is an interesting challenge to veterinarians with new opportunities for education, research, and jobs. For too long we have borrowed from our environmental future to finance our economic present. We have learned that this trajectory is unsustainable, but not irreversible. Veterinary medicine, historically centered on vertebrate health, is now emerging as a critical component of pollinator and ecosystem health management. Our One Health perspective provides for interdisciplinary collaboration with new partners to help rebuild, repair, and secure resilient ecosystems that sustain all living things. This is another important way that veterinarians can contribute to a future where people, animals, and our planet can thrive together.

As climate change accelerates ecological disruption, veterinarians are uniquely positioned to bridge animal health, ecosystem science, and agricultural sustainability in protecting pollinators and the food systems that depend on them.

Key Points

- Pollinators are bioindicators of environmental health. Protecting them supports food security, biodiversity, and climate resilience.
- Global insect declines are driven by multiple interacting stressors, including climate change, habitat loss, pollution, pathogens, pesticides, invasive species, and overexploitation.
- Climate change is increasingly a dominant driver altering pollinator phenology, forage availability, pathogen dynamics, and geographic distribution.
- Pollinator losses threaten ecosystem stability and human nutrition because many fruits, vegetables, nuts, and seeds depend on animal pollination.
- Veterinarians play an important role in pollinator health through disease surveillance, environmental monitoring, education, and collaboration within a One Health framework.
- Habitat restoration, diversified agricultural landscapes, and reduced pesticide exposure are key mitigation strategies for supporting resilient pollinator populations.
- You don't have to be a beekeeper to help. Individuals and communities can support pollinators by planting native flowers, reducing chemical use, and creating pollinator-friendly habitats.

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