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Enemies of Honey Bee (*Apis mellifera* Linn.) and their Management: A Review

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Abstract— *Honey bees (Apis mellifera) are among the most important pollinators, playing a crucial role in maintaining biodiversity and agricultural productivity. However, their colonies face numerous biotic threats that significantly impact their health, survival, and productivity. The major enemies of honey bees include parasitic mites such as Varroa destructor, which weaken colonies by feeding on bee hemolymph and transmitting viruses, and the tracheal mite (Acarapis woodi) which disrupts respiration. Pathogens like Nosema species (microsporidians) and various viral infections further compromise colony strength, leading to reduced longevity and productivity. Additionally, predators such as wax moths (Galleria mellonella and Achroia grisella) and small hive beetles (Aethina tumida) cause considerable structural damage to combs, stored honey, and brood. Minor enemies, though less destructive individually, also exert significant cumulative stress. These include ants, wasps, and spiders that invade hives for food resources, as well as birds such as bee-eaters that prey directly on foragers. Fungal diseases like chalkbrood (Ascosphaera apis) and stonebrood (Aspergillus spp.) are typically opportunistic, affecting weakened colonies under stress. Environmental stressors, pesticide exposure, and poor management practices often amplify the impact of these biotic threats. This review comprehensively synthesizes the available literature on the distribution, biology, seasonal incidence, symptoms, and management of major and minor enemies of Apis mellifera, with special reference to the Indian context. Understanding these threats is critical for devising integrated pest management strategies. Effective monitoring, hygienic management practices, and sustainable control measures are essential to safeguard Apis mellifera, ensuring their ecological services and economic value in agriculture.*

Keywords— Apis mellifera, Honey bee enemies, Varroa mite, Wax moth, Wasp, Hive beetle, Vertebrate predators, Integrated pest management.

I. INTRODUCTION

Beekeeping of European honey bee (*Apis mellifera*) is widely practiced in Himachal Pradesh, mainly through migratory methods (Kumar et al., 2022; Sharma & Verma, 2021). In recent years, there has been significant research in the field of apiculture and honey bee management, as more people domesticate bees for various products like honey and wax, as well as for business purposes (Kumar et al., 2023; Singh & Rana, 2020). However, *Apis mellifera* populations face numerous threats that can negatively impact their survival and overall health. In recent times, the rapid movement of honey bees and bee products from one location to another across countries and continents has aggravated pest problems (Rosenkranz et al., 2021; Traynor et al., 2023). Poor management practices in beekeeping weaken bee colonies, making them susceptible to pest and predator attacks.

Enemies of honey bees are those which cause disturbances and nuisance in the functioning of the colony, ranging widely in size from microscopic mites to large mammals such as bears (Ghosh et al., 2020; Sharma et al., 2022; Nain & Singh, 2024). There are reports on the incidence of a large number of insect pests infesting honey bees worldwide. Enemies are classified into two categories: pests and predators of honey bees. Predators are those animals which capture other living organisms for food (Neumann & Carreck, 2019; Evans et al., 2021; Thakur et al., 2023). The rest of the enemies cause some harm or disturbance to honey bee colonies and are considered as pests, which can cause heavy damage to bee life and their seasonal activity (Kumar et al., 2021; Abrol & Kaur, 2022; Suresh et al., 2024).

Wax moths, mites, wasps, birds, ants, bee lice, hive beetles, mice, skunks, and bears (Morse, 1999) are considered as major enemies, whereas the minor enemies include cockroaches, leaf cutter bees, robber flies, dragon flies, praying mantis, spiders (Thakur and Sharma, 1984), etc. which cause nuisance in bee colonies. These enemies are significant pests that disrupt the honey bee life cycle, making their management essential for colony health (Neumann & Carreck, 2019; Kumar et al., 2022; Ghosh et al., 2023; Nain & Singh, 2024).

The present review aims to comprehensively synthesize the available literature on the major and minor enemies of *Apis mellifera*, with emphasis on their distribution, life history, seasonal incidence, symptoms of infestation, and management strategies. While several reviews exist on individual pests, this paper provides a consolidated, holistic overview with special reference to the Indian subcontinent, highlighting region-specific challenges and knowledge gaps that warrant future research.

II. INSECT PESTS AND PREDATORS OF HONEY BEES

2.1 Wax Moth:

Galleria mellonella L. (greater wax moth) and *Achroia grisella* F. (lesser wax moth) are the most destructive pests of the beekeeping industry worldwide. Other species such as *Vitula* spp. (dried fruit moth), *Plodia interpunctela* (Hbn.), *Ephestia kuhniella* (Zell), and *E. cautella* are also associated with colonies of honey bees (*Apis cerana*, *A. mellifera*, *A. dorsata*, and *A. florea*) but cause comparatively less damage (Kumar, 1996). Among these, *G. mellonella* and *A. grisella* are responsible for enormous economic losses and are discussed in detail.

2.1.1 The Greater Wax Moth (*Galleria mellonella* L., Pyralidae: Lepidoptera):

Galleria mellonella, the greater wax moth or honeycomb moth, is a pest of global distribution. While it is a useful model insect in pathology research, it causes heavy losses to beekeepers throughout the world (Wojda, 2020; Han et al., 2023). The species was first reported as a pest in Asia, subsequently spreading to Northern Africa, Great Britain, parts of Europe, Northern America, and New Zealand. It is now distributed throughout the globe wherever honey bees are cultivated.

- **Life History:** The life cycle of *G. mellonella* proceeds through four stages: egg, larva, pupa, and adult. Generally, eggs are laid in early spring, and the moth undergoes four to six generations annually. Eggs are smooth, spherical, and pinkish to creamish white, measuring about 0.4–0.5 mm in diameter. They are usually laid in clusters within small cracks and crevices. A single female can lay an average of 300–600 eggs during her lifetime, with a maximum of up to 1800 eggs (Milum & Geuther, 1935; Mohamed & Copple, 1983; Khanbash & Oshan, 1997). The larva is white to dirty grey, measuring 3–30 mm in length. It lives inside long silken tunnels and, upon hatching, begins feeding on honey, nectar, and pollen. The larva bores tunnels into the comb and extends them toward the midrib, spinning silken galleries that provide protection from bees and trap newly emerged bees in their cells—a condition known as **gallariasis**. The larva moults 4–6 times. The pupa is brownish white when young, turning dark brown with age, measuring about 14–16 mm in length. The adult moth is heavy-bodied, brownish-grey, and ranges from 10–18 mm in length. Females are generally larger and heavier than males. In females, the outer margin of the forewing is smooth, whereas in males it bears a semi-lunar notch. The labial palps in females are extended forward, giving the head a beak-like appearance. The larval stage lasts 22–60 days (Jyothi & Reddy, 1994; Khanbash & Oshan, 1997) but may extend up to 100 days under certain conditions (Allegret, 1975). The pupal stage lasts 7–60 days (Kapil & Sihag, 1983; Jyothi & Reddy, 1993; Brar et al., 1996). The complete life cycle is typically completed within six weeks to six months, depending on environmental factors, particularly temperature, relative humidity, and diet (Burkett, 1962; Bogus & Cymborowski, 1977; Chauvin & Chauvin, 1985; Kumar, 2000).
- **Seasonal Incidence:** Seasonal incidence studies have shown that wax moths can produce multiple overlapping generations within a single year. Stored or abandoned combs, uncleaned wax residues, and weak or poorly managed colonies serve as continuous sources for wax moth population buildup. The number of generations produced annually depends largely on food availability, temperature, and habitat suitability. Wax moth activity generally extends from March to October (Garg & Kashyap, 1998), with peak infestation levels observed between June and November (Ramachandaran & Mahadevan, 1951; Brar et al., 1985; Gupta, 1987). In South India, the highest infestation rates have been reported during the dearth period when bee colonies are relatively weak and resources are scarce

(Viraktamath, 1989). During unfavorable conditions, the insect undergoes hibernation, mainly in the larval stage (approximately 70%) and to a lesser extent in the pupal stage (around 30%), within stored combs.

- **Symptoms:** Infestation of wax moths in weak colonies results in characteristic "gallerias" (Han et al., 2023; Kumar & Sharma, 2021). This condition is marked by the inability of emerging adult worker and drone bees to exit their cells, as their bodies become entangled in the silken threads spun by the larvae of *Galleria mellonella* (Kwadha et al., 2017; Wojda, 2020). This behavior exacerbates comb damage and poses a serious threat to colony health and productivity.

- **Effective Management:** Strong, well-managed colonies with adequate worker populations can resist wax moth infestation effectively, while weak colonies are more susceptible due to reduced defense activity (Ellis et al., 2013). Removal of old, damaged, or unused combs which serve as breeding sites is critical (Kwadha et al., 2017). Regular cleaning and sanitation of hives reduce larval development. Empty combs should be stored in well-ventilated and well-lit rooms. Freezing combs at –10°C to –15°C for 24–48 hours destroys all life stages of wax moths (Zhu et al., 2016; Kwadha et al., 2017). Fumigation with sulphur dioxide, acetic acid, or paradichlorobenzene (PDB) at recommended doses is also effective for stored combs.

2.1.2 The Lesser Wax Moth (*Achroia grisella* F., Pyralidae: Lepidoptera):

The lesser wax moth (*Achroia grisella*) is more widely distributed and abundant than the greater wax moth and is commonly found at comparatively higher altitudes. It is particularly troublesome in stored combs.

- **Life History:** The egg stage lasts about 2–4 days, the larval stage extends 34–48 days, the pupal stage ranges 5–12 days, and the adult moth lives for approximately 7 days (Gulati & Kaushik, 2004; Moreno-Serrano et al., 2024). The larvae of *A. grisella* measure about 15–20 mm in length (Hakanoglu et al., 2019). Adult lesser wax moths are silver-grey, without wing markings, and are smaller than the greater wax moth. They complete about four to five generations during the active season (Singh, 1962).

- **Seasonal Incidence:** The seasonal activity of *A. grisella* varies with climatic conditions, colony strength, and comb availability (Kwadha et al., 2017; Wakgari et al., 2021). Moth activity generally increases during warmer, more humid months, with peak infestation observed between June and September (Panwar, 2017–2022). During this period, high temperature and humidity favor rapid pest development and overlapping generations (Kwadha et al., 2017; Wakgari et al., 2021). Infestation is typically higher in weak colonies and stored combs, particularly during the dearth season when bee populations are reduced (Ellis et al., 2013; Mahgoub et al., 2020). Activity declines during winter due to low temperatures and limited food availability. While the greater wax moth dominates at lower altitudes, the lesser wax moth tends to be more abundant at higher altitudes and in cooler areas (Egelie et al., 2015; Mahgoub et al., 2020).

- **Symptoms:** Infestation by the lesser wax moth primarily occurs in weak colonies. The larvae prefer to feed on old, dark combs, especially those containing pollen or brood cells (Ellis et al., 2013; Kwadha et al., 2017). They are often found among wax debris accumulated on the bottom board. While feeding, the larvae create small tunnels beneath brood cells, causing brood to be pushed upward (Ellis et al., 2013; Vijayakumar, 2021). In response, bees extend the cell walls upward, resulting in a characteristic scratched appearance on the comb surface. In some cases, moth larvae cut off the caps of sealed cells, exposing pupae inside—a condition known as **"bald brood,"** a typical symptom of lesser wax moth infestation (Ellis et al., 2013; Egelie et al., 2015; Kwadha et al., 2017).

- **Effective Management:** Maintaining strong, healthy colonies is the primary defense. Fumigation of stored combs with sulphur dioxide, acetic acid, or paradichlorobenzene (PDB) at recommended doses kills all life stages. Exposure of combs to freezing temperatures or direct sunlight effectively destroys eggs, larvae, and pupae (Ellis et al., 2013; Kwadha et al., 2017; Neupane et al., 2019; Mahgoub et al., 2020; Wakgari et al., 2021).

2.2 Wasps:

Several species of wasps prey upon honey bees, causing extensive damage to colonies and sometimes leading to the loss of entire apiaries (Ghosh, 1936; Dave, 1943; Muttoo, 1949; Subbiah & Mahadevan, 1957; Sharma & Deshraj, 1985). It has been reported that about 20–25% of bee colonies desert their nests each year due to wasp attacks (Adalakha & Sharma, 1975). The large social wasps belonging to the genus *Vespa* are particularly destructive, as they are physically capable of preying on honey bees with ease. Species such as *Vespa orientalis* L. (yellow-branded brown wasp), *V. magnifica* Smith (large black wasp), *V.*

cincta F. (yellow-banded wasp), *V. ducalis* Smith, and *V. auraria* Smith (golden wasp) have been reported to attack weak and queenless colonies, destroying brood and honey stores (Kshirsagar & Mahindre, 1975; Sharma et al., 1979). They also attack forager bees in the field (Abrol, 1994; Abrol & Kakroo, 1998; Sihag, 1992). Sharma et al. (1985) recorded *V. mandarina*, *V. tropica*, *V. velutina*, and *V. basalis* as major predators of *Apis mellifera* and *A. cerana* colonies in Kangra, Himachal Pradesh. In Kashmir, *V. velutina* has been observed as a serious pest (Shah & Shah, 1991). In New Zealand, *V. germanica* was reported to have destroyed 3,900 colonies and affected over 10,000 others (Walton & Reid, 1976). Akre and Davis (1978) observed that in Japan, a group of 30 *V. magnifica* hornets could kill 25,000–30,000 bees within three hours, at a rate of one bee every 14 seconds. Hitschfeldar (1952) estimated that a single female wasp consumes 60–80 bees during her lifetime. Other wasp species associated with bee colonies include *Philanthus ramakrishnae* T. and *Palarus orientalis* Kohl, commonly referred to as bee-hunter wasps (Thakur, 1991). *V. tropica* is a swift-flying species that primarily captures forager bees during flight (Garg & Kashyap, 1998).

- **Life History:** Wasps undergo complete metamorphosis, consisting of four distinct stages: egg, larva, pupa, and adult (Spradbery, 2002; Jandth & Toth, 2015; Brock et al., 2021). Development duration varies depending on species and environmental conditions such as temperature and food availability (Smith et al., 2013). The life cycle begins when the fertilized queen lays eggs in hexagonal cells within the nest. Eggs are small, oval, and whitish, with the egg stage lasting 3–5 days. After hatching, larvae are fed by worker wasps on chewed insects or protein-rich food. The larval stage generally lasts 10–14 days, during which larvae undergo several molts and increase rapidly in size. Mature larvae spin silken caps over cells and pupate. During this stage, internal reorganization occurs, leading to the development of wings, legs, and other adult structures (Matsuura & Yamane, 2020; Brock et al., 2021). The pupal period lasts 8–15 days. After emergence, adult wasps are divided into queens, workers, and males (drones) in social species such as *Vespa* and *Vespula*. The queen initiates nest building and lays eggs, while workers perform brood care, foraging, and defense. Males usually appear later in the season for mating. In temperate regions, the wasp life cycle is annual; only fertilized queens survive winter, while workers and males die due to cold. Queens emerge in spring to start new colonies. In tropical and subtropical regions, overlapping generations may occur, allowing colonies to persist for several months or year-round. The entire cycle from egg to adult is completed in about 30–45 days, depending on species and environmental factors (Spradbery, 2002; Mahgoub et al., 2020).

- **Seasonal Incidence:** The seasonal incidence of wasps in honey bee colonies varies with climatic conditions, food resource availability, and wasp species' developmental cycle (Abrol, 2006; Archer, 2012; Reddy et al., 2014). Wasp activity generally begins with the onset of warm weather in late spring and increases during summer, reaching peak during the post-monsoon period (July to October) (Kumar et al., 2015; Sharma et al., 2018; Ghosh & Dey, 2020). During this time, wasps such as *Vespa orientalis*, *V. tropica*, *V. auraria*, and *V. velutina* are frequently observed attacking honey bee colonies. Population declines sharply with colder months, with very little activity recorded from December to February. The highest incidence of wasp attacks occurs when honey bee colonies become weak due to reduced floral resources or brood rearing, making them more vulnerable to predation. Wasp abundance is also influenced by temperature and humidity, which favor breeding and foraging. In regions like Kangra and Kashmir, wasp populations show distinct seasonal trends, with maximum predation pressure during late summer and early autumn (Abrol, 2006; Sharma et al., 2018). Similar findings have been reported in other parts of India and abroad, indicating that wasp attacks are closely linked to environmental conditions and wasp life cycles. Monitoring and preventive measures against wasp attacks should be intensified during the peak season, particularly from July to October, to minimize colony losses (Abrol, 2006; Reddy et al., 2014; Monceau et al., 2014).

- **Symptoms:** Colonies under attack show a significant decline in foraging trips and guarding response, as bees become fearful and avoid the hive entrance (Abrol, 2006). Dead bees and body parts scattered near the hive indicate predation by wasps like *V. magnifica* and *V. velutina*. Wasps often invade weak or queenless colonies, destroying brood cells and feeding on larvae, pupae, and stored honey (Abrol & Kapil, 1994; Archer, 2012; Sharma et al., 2018; Brock et al., 2021).

- **Effective Management:** Locating and destroying wasp nests around apiaries during early spring or the nesting season helps reduce populations before they become harmful. Bait traps containing sugar syrup, fruit juice, or meat pieces mixed with insecticide can be placed near apiaries to attract and kill adult wasps. Strong colonies with sufficient worker populations are better able to defend themselves against wasp attacks than weak or queenless ones (Abrol & Kapil, 1994; Archer, 2012; Reddy et al., 2018; Sharma et al., 2018; Brock et al., 2021).

2.3 Mites:

2.3.1 Varroa Mite (*Varroa destructor* / Varroa *jacobsoni*):

This mite is a native ectoparasite of *Apis cerana* across Asia and was first reported in Indonesia in 1904 (Anderson & Trueman, 2000; Rosenkranz et al., 2010). Since the introduction of *Apis mellifera* beekeeping in Asia, the mite has been responsible for significant damage in both temperate and tropical regions. Varroa infestation weakens honey bee colonies, leading to reduced honey production (Nazir et al., 2019). Presently, this parasite has spread worldwide, except Australia and New Zealand. In temperate Asia, most beekeepers agree that Varroa damage is a major constraint to successful *A. mellifera* beekeeping, while in tropical Asia, success is limited by the loss of *A. cerana* colonies through absconding—which is far less serious and frequent than damage to *A. mellifera*. *Varroa jacobsoni* multiplies faster on *Apis cerana*, whereas *Varroa destructor* is a more serious problem for *Apis mellifera* (Anderson & Trueman, 2000; Navajas et al., 2010).

- **Life History:** *Varroa destructor* is an external parasitic mite that primarily attacks the brood and adult bees of *Apis mellifera* (Rosenkranz et al., 2010). Its life cycle is closely linked with the developmental stages of honey bee brood and includes both **phoretic** (on adult bees) and **reproductive** (within capped brood cells) phases. The female Varroa mite attaches to adult bees, especially nurse bees, and feeds on the bee's hemolymph and fat body tissues. When a nurse bee enters a brood cell to feed the larva, the mite also enters the cell, preferably drone brood cells which offer a longer development period. Once the cell is capped, the mite begins its reproductive phase. Inside the sealed cell, the foundress mite lays her first egg about 60–70 hours after capping, which develops into a male, followed by successive female eggs at 30-hour intervals. The male and female offspring mature within the brood cell, and mating occurs before the adult bee emerges. When the young bee emerges, fertilized female mites exit the cell and attach to other adult bees, continuing the cycle. The developmental period of *Varroa* mite from egg to adult is approximately 6–7 days for males and 7–9 days for females (Rosenkranz et al., 2010). The lifespan of female mites varies; they can survive 2–3 months in summer and up to 5–6 months in winter, depending on environmental conditions and brood availability. Due to rapid reproduction and association with brood, Varroa mites produce multiple overlapping generations, causing heavy infestations in a short period and leading to colony weakening and eventual collapse if not managed properly (Nazzi & Le Conte, 2016; Giacobino et al., 2020).

- **Seasonal Incidence:** The seasonal incidence of *Varroa destructor* in *Apis mellifera* colonies varies according to climatic conditions, brood availability, and colony strength (Rosenkranz et al., 2010; Giacobino et al., 2015). The mite population shows a cyclic pattern throughout the year, increasing during periods of intense brood rearing and declining when brood production is minimal. During spring and early summer, when colony growth and brood rearing peak, the mite population begins to multiply rapidly. The abundance of capped brood cells provides favorable conditions for *Varroa* reproduction (Martin, 2001; Dietemann et al., 2020). Infestation continues to increase and usually reaches its maximum level during late summer to early autumn, coinciding with the highest brood density (Beaurepaire et al., 2015; Traynor et al., 2020). As temperatures decline in late autumn and winter, brood rearing is reduced or temporarily ceases, restricting mite reproduction. During this broodless period, mites remain on adult bees in the phoretic stage. Although population growth slows, mites survive on adult bees and resume reproduction once brood rearing starts again in spring. In tropical and subtropical regions where brood rearing continues year-round, *Varroa destructor* maintains continuous reproduction, resulting in overlapping generations and persistent infestation (Dietemann et al., 2020). In temperate regions, seasonal brood breaks naturally help reduce mite populations. Therefore, peak *Varroa* incidence is typically observed during late summer and early autumn, making this period critical for monitoring and implementing effective control measures (Rosenkranz et al., 2010; Traynor et al., 2020).

- **Symptoms:** Infestation of *Varroa destructor* causes several visible and behavioral symptoms in *Apis mellifera* colonies. Infested brood often fails to develop properly. Emerging adult bees may show deformed wings, shrunken abdomens, and crippled legs, commonly associated with Deformed Wing Virus (DWV) transmission (Francis et al., 2013). The brood comb appears scattered or patchy due to the removal of infested larvae and pupae by worker bees, indicating hygienic behavior in response to mite attack. Continuous infestation leads to reduced brood production, resulting in decreased adult bee population and colony weakening (Martin & Medina, 2004; Traynor et al., 2020).

- **Effective Management:** Effective management of *Varroa destructor* requires an integrated approach combining cultural, mechanical, biological, and chemical methods (Rosenkranz et al., 2010; Dietemann et al., 2020; Mondet et al., 2021). Periodic examination of brood and adult bees using methods such as the sugar roll test, alcohol wash, or drone brood uncapping helps in early detection and timely intervention before infestation reaches damaging levels. Introducing or breeding Varroa-tolerant or hygienic strains of *A. mellifera* that can detect and remove infested brood naturally helps reduce mite load. Treatments with formic acid, oxalic acid, thymol, and menthol are effective in controlling mites when used properly (Gregorc & Planinc, 2012). However, emerging acaricide resistance is a growing concern, necessitating rotation of active ingredients and integration of non-chemical methods.

2.3.2 Tracheal Mite (*Acarapis woodi*):

The tracheal mite (*Acarapis woodi*) is an endoparasite that infests the tracheal system of adult honey bees belonging to all three castes—workers, drones, and queens (Otis & Scott-Dupree, 2002; Sammataro et al., 2013). This mite was first reported in *Apis mellifera* colonies in Europe in 1921. In India, it was initially recorded in *Apis cerana* colonies in 1957 and later in *Apis mellifera* colonies in 1994. Presently, it has become a major pest causing serious problems to honey bee colonies, particularly in North America (Traynor et al., 2020).

- **Life History:** *Acarapis woodi* is an internal parasite that completes its entire life cycle within the tracheal system of adult honey bees. The female mite enters the thoracic tracheae of newly emerged bees through the spiracles. Once inside, she lays eggs along the inner walls of the tracheae, where developing mites feed on the host's hemolymph (Singh et al., 2015). Eggs hatch within 3–4 days, and immature stages (larvae and nymphs) develop over 11–15 days. The complete life cycle from egg to adult mite takes about 14–20 days, depending on temperature and humidity. Adult female mites live for about 30 days, during which they continue to reproduce within the tracheal system (Nazzi & Le Conte, 2016). Mating occurs inside the trachea, and mated females leave the host bee to infest young bees, ensuring continuation of infestation within the colony. Transmission primarily occurs through direct contact among bees, especially during clustering or grooming behavior. This internal parasitism weakens the respiratory system of bees, reduces flight ability, shortens lifespan, and ultimately leads to colony decline if infestations are severe (Singh et al., 2015; Traynor et al., 2020).

- **Seasonal Incidence:** The incidence of tracheal mite shows marked seasonal variation. Infestation levels are generally higher during winter and early spring, when bees form tight clusters and have close contact, favoring mite transmission. During this period, adult bee lifespan increases, providing more time for mite reproduction within the tracheae (Traynor et al., 2020; Mondet et al., 2021). As temperature rises in summer, infestation rate declines due to increased bee activity and reduced contact among individuals. Seasonal studies have shown that maximum infestation occurs from December to March, while minimum levels are recorded during May to August, depending on local climatic conditions (Sammataro & Avitabile, 2011).

- **Symptoms:** Infested bees often show disjointed wings or a "K-wing" condition and are seen crawling near the hive entrance, unable to fly (Van Engelsdorp & Meixner, 2010). Due to blockage of the tracheal system, affected bees become weak and lose flight ability. Infested worker bees die prematurely, leading to a noticeable reduction in the colony's adult population.

- **Effective Management:** Approved miticides like menthol crystals can be applied during warm weather when vapors circulate effectively in the hive. Menthol is usually placed above the brood chamber for several weeks (Otis & Scott-Dupree, 2002). Natural products such as thymol, wintergreen oil, and formic acid fumigation are effective in reducing mite populations without harming bees. Maintaining strong, healthy colonies with adequate food supply, proper ventilation, and timely replacement of old queens reduces the spread and impact of mites (Traynor et al., 2020).

2.4 Bee Lice:

The bee louse (*Braula coeca*) is a small, wingless fly found as an ectoparasite on adult honey bees. It measures about 1.5 mm in length and usually attaches to the head or thorax of worker bees and queens to feed on nectar or honey from the bee's mouthparts (Sammataro et al., 2000; Ellis & Munn, 2005). The insect does not suck blood, but its presence can cause irritation and interfere with normal feeding and grooming behavior. *Braula coeca* is widely distributed in Europe, Asia, Africa, and North America, and has also been reported from various parts of India, particularly in regions where *Apis mellifera* colonies are reared. Infestation is usually more noticeable in weak colonies or during honey flow seasons when food resources attract adult lice (Chauhan & Singh, 2000; Pernel et al., 2005). Heavy infestations can disturb the queen by clustering around her head, reducing egg-laying efficiency and overall colony strength. Additionally, the larvae tunnel through wax capping of stored honey cells, which may lead to contamination and minor damage to combs. Although not a major pest, severe infestations can stress the colony and reduce honey quality and productivity (Ellis, 2016; Qaiser et al., 2021).

- **Symptoms:** Tiny, wingless insects (about 1.5 mm long) can be seen crawling on the head and thorax of worker bees and queens, often mistaken for mites. Bee lice frequently cluster around the queen's head, interfering with feeding and grooming, which leads to reduced egg-laying and colony weakening. The larvae of *Braula coeca* tunnel through the wax capping of stored honey cells, causing visible marks and contamination of combs or honey (Sammataro & Avitabile, 2011; Chauhan & Singh, 2020).
- **Effective Management:** Maintaining strong, healthy colonies is essential, as bee lice prefer weak or poorly managed hives. Regular inspection and proper sanitation aid in early detection and control. Heavily infested queens should be replaced, since bee lice often gather around the queen's head and reduce her egg-laying efficiency (Sharma et al., 2022). Fumigation with formic acid or menthol vapors during warm weather is effective in reducing adult louse populations without harming bees (Underwood & Currie, 2009; Chauhan & Singh, 2020).

2.5 Ants:

Ants are opportunistic insects that invade honey bee colonies to steal honey, pollen, and brood. Several species, including black ants, red ants, and carpenter ants, are commonly found attacking bee hives (Kumar et al., 2018; Sharma et al., 2021). They are highly attracted to the sweet smell of honey and wax and often build nests near or inside apiaries (Hepburn & Radloff, 2011). Ant infestation in beehives is a widespread problem reported from tropical and subtropical regions across Asia, Africa, Europe, and the Americas (Kiatoko et al., 2016; Qaiser et al., 2020). In India, ant attacks are common in warm and humid areas, especially during summer and rainy seasons (Kumar et al., 2019; Singh & Rathore, 2023). Ants cause stress to bees by constantly disturbing the colony, stealing food, and sometimes destroying brood combs (Ellis et al., 2010; Mutinelli, 2011). Their presence forces worker bees to spend more time defending the hive rather than foraging, which reduces colony strength and productivity. In severe cases, colonies may abscond from the hive due to continuous disturbance and food loss caused by heavy ant infestation (Kiatoko et al., 2016; Singh & Rathore, 2023).

- **Symptoms:** Large numbers of ants are seen crawling on the hive stand, cover, and combs, especially near honey stores (Hepburn & Radloff, 2011; Kumar et al., 2017). Worker bees become agitated and defensive, spending more time guarding the hive instead of foraging. Due to honey and brood theft, bees may abandon the hive (absconding) or show a noticeable decline in population and productivity (Kumar et al., 2019; Qaiser et al., 2020).
- **Effective Management:** Placing hive stands in ant-proof containers filled with oil, water, or kerosene prevents ants from climbing into the hive (Ellis et al., 2010; Kumar et al., 2018; Singh & Rathore, 2023). Keeping the apiary clean and free from food waste or spilled honey, and regularly removing nearby ant nests or trails, are essential (Sharma et al., 2021). Application of grease bands, ash, or chalk lines around hive stands acts as repellents (Kumar et al., 2019).

2.6 Hive Beetles:

The small hive beetle (*Aethina tumida*) is a destructive pest of honey bee colonies, belonging to the family Nitidulidae. Adult beetles are dark brown to black, about 5–7 mm long, and usually found hiding in hive corners, under frames, or in brood combs (Ellis & Munn, 2005; Neumann & Ellis, 2008). The larvae feed on pollen, honey, and brood, causing serious damage to combs and stored honey (Hood, 2011; Mutinelli et al., 2014). This pest is native to sub-Saharan Africa but has now spread to North America, Australia, Europe, and parts of Asia, including recent reports from India (Kumaranag et al., 2025). Infestation is most severe in warm and humid climates, which favor beetle reproduction and survival. Hive beetles cause fermentation and spoilage of honey, leaving a slimy residue with a foul odor. Their tunneling through combs destroys wax and brood, leading to colony weakening. In severe infestations, adult bees may abandon the hive due to continuous disturbance and contamination of food stores (Ellis et al., 2010; Cappa et al., 2022).

- **Symptoms:** Fermentation of honey by beetle larvae produces a slimy residue and a strong, rotten smell inside the hive (Ellis & Munn, 2005; Neumann & Ellis, 2008; Hood, 2011). Beetle larvae tunnel through combs, destroying brood cells, pollen, and stored honey, leaving visible trails and debris. Continuous movement and feeding of beetles irritate bees, causing stress and sometimes leading to absconding of the entire colony (Schafer et al., 2020; Cappa et al., 2022; Kumar et al., 2021).

- **Effective Management:** Maintaining healthy, populous colonies is critical, as strong bee populations can effectively chase and confine beetles, preventing heavy infestation. Regular cleaning of hive floors, removal of debris, and discarding of old combs reduce breeding sites for beetles and larvae (Hood, 2011; Schafer et al., 2020). Installation of beetle traps or oil-based traps inside hives, and application of soil treatments (such as diatomaceous earth) around the apiary to kill pupating larvae in the ground, are effective control measures (Neumann et al., 2016; Kumar et al., 2021; Cappa et al., 2022)

III. VERTEBRATE PREDATORS

3.1 Birds:

Birds are considered minor natural enemies of honey bees, as several insectivorous species prey on foraging bees during flight or near the hive entrance (Abrol, 2012; Sharma & Kumar, 2017). Common bee predators include bee-eaters (*Merops orientalis*), drongos (*Dicrurus macrocercus*), and kingbirds, which catch bees in the air (Bista et al., 2020; Fichtel et al., 2016). These birds often target flying worker bees, especially during active foraging periods in the morning and evening (Ali et al., 2018; Kumar et al., 2021). According to various studies, bird predation on honey bees has been reported from Asia, Africa, and southern parts of Europe, particularly in India where the green bee-eater is a frequent pest in apiaries (Kumar et al., 2022; Gupta et al., 2024). Their activity increases during spring and summer months, coinciding with high bee activity. Heavy predation can lead to a reduction in foraging population, causing a decline in nectar and pollen collection, and ultimately lowering honey yield. Continuous attacks may also disturb colony behavior, forcing bees to remain inside the hive and reducing overall productivity (Sharma et al., 2017; Bista et al., 2020).

- **Symptoms:** A noticeable decline in the number of worker bees leaving the hive is observed, as birds catch bees during flight and near the entrance (Abrol, 2012; Singh & Rana, 2015). Colonies become highly agitated and defensive, with bees showing reluctance to forage or remain outside due to continuous bird attacks (Bista et al., 2020). Continuous predation reduces the forager population, leading to lower nectar and pollen collection and ultimately decreased honey production (Ali et al., 2018; Kumar et al., 2021; Gupta et al., 2024).
- **Effective Management:** Installation of reflective tapes, scarecrows, or sound-emitting devices near the apiary can frighten away bee-eating birds and reduce their visits (Abrol & Kapil, 2019). Apiaries should be established away from bird nesting or roosting areas, such as tall trees, power lines, or open fields commonly used by bee-eaters and drongos (Singh & Rana, 2015; Bista et al., 2020). Protective nets or wire screens around the apiary during peak bird activity periods can prevent birds from catching bees in flight near hive entrances (Kumar et al., 2021; Gupta et al., 2024).

3.2 Bears:

Bears are recognized as major vertebrate predators of honey bee colonies, primarily attracted by honey, brood, and pollen (Abrol, 2012; Raj & Rana, 2016; Mishra et al., 2021). Species such as the Asiatic black bear (*Ursus thibetanus*), sloth bear (*Melursus ursinus*), and American black bear (*Ursus americanus*) are known to raid beehives. These attacks usually occur at night when colonies are less active (Kumar et al., 2019). According to various reports, bear damage to apiaries is reported from Asia, Europe, and North America, particularly in hilly and forested regions like the Himalayan foothills, Himachal Pradesh, Uttarakhand, and North-Eastern India (Singh & Thakur, 2017). Bears use their strong claws to tear apart hives, destroying wooden boxes and combs while consuming honey and larvae. Such attacks cause complete destruction of colonies, resulting in loss of bees, brood, and hive materials (Abrol, 2012; Sharma et al., 2023). Frequent raids lead to economic losses, disturbance of apiary sites, and sometimes migration or absconding of surviving colonies due to continuous stress and habitat disruption (Mishra et al., 2021; Kumari et al., 2024).

- **Symptoms:** Wooden boxes and combs are broken, scattered, or overturned, showing clear signs of claw or bite marks from bear attacks (Joshi et al., 2018; Raj & Rana, 2016). Colonies experience complete destruction of combs, resulting in loss of adult bees, brood, and stored honey (Kumar et al., 2019; Sharma et al., 2023). Surviving bees become highly disturbed and aggressive, and in many cases, abandon the hive (abscond) due to repeated bear raids and habitat disturbance (Mishra et al., 2021; Kumari et al., 2024).
- **Effective Management:** Installation of strong fencing, preferably electric fences, around the apiary is effective in preventing bears from entering and damaging hives (Sathyakumar & Bashir, 2020). Apiaries should be established away from forest edges or known bear habitats, preferably in open, monitored areas to reduce attack risk (Raj & Rana,

2016). Night-time surveillance and use of light, noise, or scent repellents (such as burning kerosene or chemical deterrents) can scare away bears from approaching the apiary (Mishra et al., 2021; Kumari et al., 2024).

3.3 Other Vertebrate Pests:

In addition to birds and bears, other vertebrate pests such as **mice, rats, skunks, and lizards** also cause damage to honey bee colonies. Mice and rats often enter hives during winter, building nests and chewing combs, wax, and wooden parts. Skunks scratch at hive entrances at night to capture bees as they emerge, leading to colony disturbance and reduced populations. Lizards and frogs occasionally prey on bees near hive entrances, though their impact is generally minimal. Management of these pests includes hive stand elevation, entrance reducers, trapping, and exclusion fencing (Morse, 1999; Abrol, 2012).

IV. MINOR ENEMIES

Several minor enemies cause occasional or localized nuisance to honey bee colonies. These include **cockroaches**, which seek shelter and food in hives, contaminating combs; **robber flies** and **dragonflies**, which prey on foraging bees in flight; **praying mantis**, which capture bees visiting flowers; and **spiders**, which build webs near hive entrances to trap bees (Thakur & Sharma, 1984). While individually these enemies cause limited damage, cumulative stress from multiple minor pests can contribute to colony weakening, particularly when colonies are already under pressure from major pests, diseases, or nutritional stress. Management typically involves good apiary hygiene, removal of harborages, and physical barriers.

V. INTEGRATED MANAGEMENT OF HONEY BEE ENEMIES

Effective management of honey bee enemies requires an **integrated approach** that combines multiple strategies rather than reliance on any single method. Key principles of integrated pest management (IPM) for honey bee colonies include:

1. **Monitoring and Early Detection:** Regular inspection of colonies for signs of pest infestation using standardized sampling methods (e.g., sugar roll for Varroa, visual inspection for wax moths, wasp trapping).
2. **Cultural Practices:** Maintaining strong, healthy colonies through proper nutrition, disease management, and queen replacement; ensuring adequate colony strength is the single most effective defense against most pests.
3. **Sanitation:** Regular cleaning of hive floors, removal of old combs, proper storage of empty equipment, and disposal of debris reduce breeding sites for wax moths, hive beetles, and other pests.
4. **Physical and Mechanical Controls:** Use of screened bottom boards, drone brood removal, freezing of combs, hive stands with ant-proof barriers, electric fencing, and bird netting.
5. **Biological Controls:** Promotion of hygienic bee strains, use of entomopathogenic nematodes for hive beetle larvae, and conservation of natural enemies of pests where applicable.
6. **Chemical Controls:** Judicious use of approved acaricides, fumigants, and repellents, with strict adherence to dosage, timing, and withdrawal periods to minimize residues in hive products and mitigate resistance development.
7. **Beekeeper Training and Extension:** Capacity building of beekeepers in pest identification, monitoring, and management through demonstrations, training programs, and extension literature.

VI. KNOWLEDGE GAPS AND FUTURE RESEARCH NEEDS

Despite substantial research on honey bee enemies, several knowledge gaps remain:

1. **Impact of Climate Change:** How shifting temperature and rainfall patterns will alter the distribution, phenology, and population dynamics of major pests like Varroa mites, wax moths, and wasps.
2. **Native vs. Invasive Pests:** Comparative studies on the impact of invasive species (e.g., *Vespa velutina*, *Aethina tumida*) versus native pests in different agro-ecological regions of India.
3. **Resistance Management:** Surveillance of acaricide resistance in Varroa populations and development of resistance management strategies.
4. **Non-Chemical Controls:** Validation and refinement of biotechnical and biological control methods under tropical field conditions.

5. **Economic Thresholds:** Establishment of region-specific economic injury levels for major pests to guide treatment decisions.
6. **Interaction Effects:** Understanding synergistic interactions among pests, pathogens, pesticides, and nutritional stress in driving colony losses.
7. **Indigenous Knowledge:** Documentation and validation of traditional beekeeping practices for pest management.

Galleria mellonella
(Greater wax moth)

Achroia grisella
(Lesser wax moth)

Vespula germanica
(Wasp)

Varroadestructor
(Varroa mite)

Acarapis woodi
(Tracheal mite)

Braula coeca
(Bee lice)

Aethina tumida
(Hive beetle)

Ursus thibetanus
(Bear)

FIGURE 1: Enemies of honey bees

VII. SUMMARY AND CONCLUSION

Honey bee colonies are affected by a wide range of enemies, including moths, wasps, mites, bee lice, ants, hive beetles, birds, bears, and other vertebrate and invertebrate pests. Each poses distinct threats to colony health and productivity, causing damage by destroying combs, feeding on brood or honey, weakening adult bees, and in severe cases, leading to absconding or colony collapse. The severity of infestation varies with season, climate, and management practices adopted by beekeepers.

Among arthropod pests, **Varroa destructor** remains the most serious global threat due to its direct damage and role as a vector of lethal viruses. **Wax moths** cause significant economic losses, particularly to weak colonies and stored combs. **Wasps**, especially *Vespa* species, are major predators in many regions, capable of decimating entire apiaries. **Small hive beetles** are an emerging invasive threat in India requiring vigilant monitoring. **Vertebrate predators** such as bears and birds cause localized but severe damage.

Effective management of these enemies relies on an **integrated approach** combining good apiary hygiene, strong colony maintenance, regular monitoring, and timely preventive measures. The use of biological, physical, and cultural control methods, along with judicious application of approved chemicals, helps minimize pest impact while preserving bee health and product quality. Proper site selection, beekeeper awareness, and region-specific strategies are crucial for early detection and effective control.

This review highlights that while substantial knowledge exists on individual pests, there is a need for **synthesis, contextualization to Indian conditions, and translation into accessible extension materials** for beekeepers. Future research should prioritize climate change impacts, resistance management, non-chemical controls, and economic thresholds. Ultimately, sustainable management of honey bee enemies requires continuous observation, scientific intervention, and collaborative efforts among researchers, extension agencies, and beekeeping communities to ensure healthy colonies, improved pollination services, and enhanced honey production.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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