

# Chapter 13

## Biodiversity Issues and Challenges:

### Non-agricultural Insects



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#### 13.1 Introduction

With more than one million named species (10,78,506), insects are the most diverse terrestrial creatures on the planet, representing around 75% of the global fauna (Table 13.1; Fig. 13.1) with more than 80% yet to be described (Zhang 2011, 2013a, b; Adler and Foottit 2017). Stork (2018) assessed more than 5.5 million insect species on our planet. This remarkable richness and diversity of insects on land is the outcome of their evolutionary success. They became abundant in the Middle Silurian to Early Devonian period (420 to 405 million years ago) and by the Late Carboniferous (323 to 299 million years ago) (Labandeira 2018). They are the significant components of both terrestrial and aquatic ecosystems from the equator to the arctic region and from sea level to the snowfields of the highest mountains, on land, in air, and in water—almost everywhere. Insects contribute invaluable ecosystem functions such as nutrient cycle, pollination, and seed dispersals. They serve as a significant food source for other organisms, help in the biocontrol of other organisms (such as predators, parasites), and maintain soil structure and fertility. Meantime, they are profoundly beneficial as pollinators. They often come into direct competition with humans, as pests of agriculture and stored products and as vectors of life-threatening diseases.

In modern classification, the classes, Insecta, Collembola, Protura, and Diplura form subphylum Hexapoda in phylum Arthropoda (Zhang 2013a, b). The first entomologist who made extensive studies of Indian insects was Fabricius (1775, 1782, 1787, 1793, 1798, 1804), and the publication of Carl Linnaeus (1758) provided the earliest record of Indian insects, with descriptions of 28 species. Later, different workers carried out the compilation of India's data on insect fauna from time to time. Maxwell-Lefroy and Howlett (1909) included 25,700 species of

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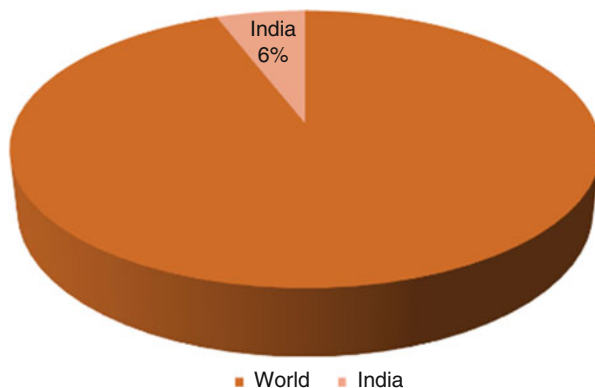
**Table 13.1** Insect diversity (Arthropoda: Hexapoda) of the world and India

Classes	Orders	Number of species		
		World	India	Percentage of world
Collembola		9000	345	3.83
Protura		816	20	2.5
Diplura		976	18	1.84
Insecta		1,067,902	66,728	6.2
	1. Archaeognatha	513	11	2.14
	2. Zygentoma	564	29	5.14
	3. Ephemeroptera	3700	152	4.1
	4. Odonata	6312	496	7.9
	5. Orthoptera	28,650	1166	4.06
	6. Phasmida	3350	140	4.2
	7. Embioptera	457	32	7.0
	8. Plecoptera	3700	146	3.94
	9. Dermaptera	2375	293	12.3
	10. Mantodea	2519	184	7.3
	11a. Blattodea (cockroaches)	4837	181	3.74
	11b. Blattodea (termites)	2942	295	6.63
	12. Psocoptera	5611	126	2.24
	13. Phthiraptera	5316	466	8.8
	14. Thysanoptera	6288	754	12.0
	15. Hemiptera	107,180	6479	6.04
	16. Hymenoptera	154,067	10,605	6.9
	17. Strepsiptera	627	28	4.5
	18. Coleoptera	386,755	22,334	5.8
	19. Neuroptera	5917	327	5.5
	20. Megaloptera	386	30	7.8
	21. Raphidioptera	253	5	2.0
	22. Trichoptera	16,267	1299	7.6
	23. Lepidoptera	158,423	13,694	8.6
	24. Diptera	157,971	7382	4.6
	25. Siphonoptera	2185	51	2.3
	26. Mecoptera	737	23	3.1
	Total (Collembola+Protura +Diplura+Insecta)	1,078,506	67,111	6.2

insects from India and adjacent countries in their famous book *Indian Insect Life*. Beeson (1941) and Menon (1965) estimated the number of species from India to be 40,000 and 50,000, respectively.

Varshney (1997) reported 51,450 species under 589 families. Subsequently, Varshney (1998) reported the occurrence of 59,353 species belonging to 619 families in India. Recently Chandra (2011) analyzed the insect fauna of states and union territories of India and reported 63,760 species under 658 families. In this chapter, an

**Fig. 13.1** Insect diversity across the globe and India

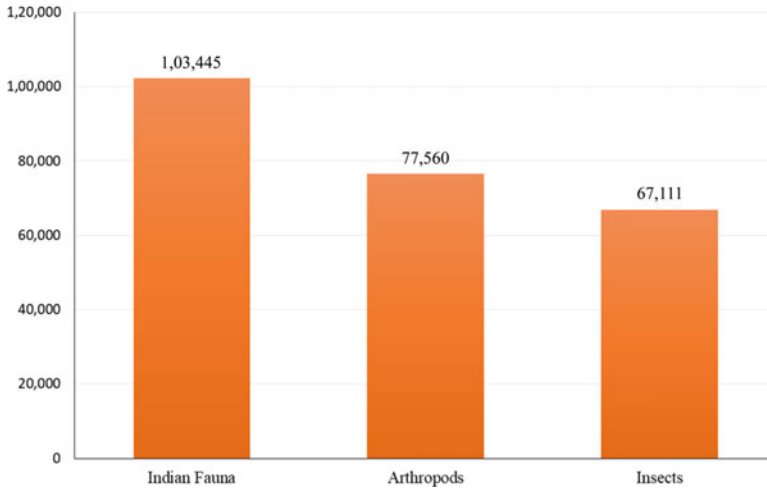


attempt has been made to review and update the known insect diversity of India with emphasis on their diversity in the freshwater ecosystem, mangroves, soil, and forests. Additionally, the diversity of insects in the Himalayas, Trans-Himalaya, deserts, and islands is concisely presented along with edible insects, invasive alien insect species, and insects of medical and veterinary significance. A list of threatened insects is also provided with the major threats faced by insect populations in the country.

### ***13.1.1 Insect (Arthropoda: Hexapoda) Diversity of India***

Owning four of the globally recognized biodiversity hotspots—Himalaya, Indo Burma, Western Ghats and Sri Lanka, and Sundaland—India is represented by 103,445 faunal species of different terrestrial and marine phyla (Chandra et al. 2019d), of which phylum Arthropoda alone holds over 77,560 species (74.8%) (Fig. 13.2). 64.8% of the overall faunal diversity of the country (67,111 species) exclusively includes insects (Fig. 13.2), represented by four classes of subphylum Hexapoda: Collembola (345 species), Protura (20 species), Diplura (18 species), and Insecta (66,728 species) (Table 13.1). Eight insect orders—Coleoptera, Lepidoptera, Hymenoptera, Diptera, Hemiptera, Orthoptera, Thysanoptera, and Odonata—form the majority (94%) of the insects in the country. In contrast, the remaining 6% of species constitute 18 small orders. The order Coleoptera has the highest diversity at the family level (114) followed by Hemiptera (92), Diptera (87), Lepidoptera (84), and Hymenoptera (65).

Only 4.7% (3130 species) of insect diversity of the country depend on agroecosystems (Chandra et al. 2020b) (Table 13.2). Insects in the agroecosystem play a vital role in crop production as pests of crops, predators of other insects, and parasitoids. The majority of the insects (63,981 species), directly and indirectly, occupy the forest ecosystem. Except for the few pest species, little is known about the bionomics, host association, and habitat of a significant proportion of species.



**Fig. 13.2** Comparison of overall faunal diversity of India with arthropods and insects

**Table 13.2** Known species richness of total fauna and insects in different ecosystems and biogeographic zone of India

Ecosystem/biogeographic zone	Number of species		Percentage against overall fauna of ecosystem/biogeographic zone	Percentage against insect fauna of India
	Fauna	Insects		
Agroecosystem	5820	3130	53.6	4.7
Freshwater	9456	5014	52.6	7.4
Soil (Belowground)	22,586	13,711	60.7	20.5
Mangroves	4822	1461	30.3	2.9
Himalaya	30,615	25,064	81.9	37.5
Trans-Himalaya (Cold Desert)	3324	2291	68.9	3.4
Desert (Thar)	3346	1580	46.7	2.3
Island	11,009	3572	32.4	5.3

The Himalayan ecosystems are comparatively diverse than other geographical regions, including 37.5% of the overall insect diversity (Table 13.2).

Though the insect diversity of India is comparatively rich and well known, revisionary works on smaller and lesser-known groups are required. There is also a need to write the Fauna of India on various families of the economically essential groups, as the Fauna of British India volumes are comparatively old and outdated. It is also necessary to undertake studies on DNA barcoding, especially pests and biological control agents, to solve the problems of identification in species complexes. Despite their ecological importance, the conservation of insects in India has not yet received much attention. Therefore, it is required to investigate the effect of climate change and habitat fragmentation on the diversity and distribution of insects.

### ***13.1.2 Class Collembola***

Collembolans are small-sized, wingless, and entognathous insects, predominately found in soil and litter (Gullan and Cranston 2014). Nine thousand species represent global diversity (Bellinger et al. 1996–2020), of them, 3.8% (345 species, 114 genera, 14 families) are known from India (Mandal 2018a, b, 2019). They are widespread and found everywhere, even in the Antarctic and Arctic (Christiansen and Bellinger 2003). They inhabit all habitats like mosses, under stones, in caves, in ant and termite nests, and also in the intertidal zone on the coast, on the surfaces of lakes and ponds, or snowfields, except the open oceans and deep areas of large lakes (Hagvar 1983; Rusek 1998; Christiansen and Bellinger 2003). They are specialized feeders on soil microbiota and play significant roles in the breakdown of leaf litter control aiding in the process of humification and enhancing soil fertility (Parkinson 1983). Collembolans are bio-indicator of soil health as they are extremely susceptible to changes in soil conditions (Ponge 2014).

### ***13.1.3 Class Protura***

Protura include tiny apterygote insects lacking eyes, antennae, and cerci with entognathous mouthparts (Allen 2003; Pass and Szucsich 2011). The global diversity includes 816 described species belonging to 76 genera in 7 families and 3 orders (Galli et al. 2018). Presently only 20 species belonging to 10 genera and 3 families are known from India, restricted to the Western Ghats (Kerala), of which 17 species are endemic (Prabhu 1986; Chandra 2011). They are commonly recorded from forest habitats and found in decaying organic matters, soil, moss, peat, leaf litter, and under bark and rotting wood with sufficient moisture (Pass and Szucsich 2011). They are specialized mycorrhizal feeders and compete for their trophic niche with other soil invertebrates (Bluhm et al. 2019). Proturan assemblages are highly susceptible to biogeochemistry and resource availability to forest disturbances (Sterzyńska et al. 2020).

### ***13.1.4 Class Diplura***

Diplura includes small- to medium-sized wingless insects with two cerci at the end of the abdomen and moniliform antennae (Gullan and Cranston 2014). They are abundant in humid places, in soil or under bark, living on decaying vegetation or as predators. The world fauna of Diplura comprises 976 species, and 18 species represent the Indian fauna in 9 genera under 4 families, of which 12 species are endemic (Mandal 2010a, b; Chandra 2011; Yadav 2017a, b, 2018).

### **13.1.5 Class Insecta**

#### **13.1.5.1 Order Archaeognatha**

Archaeognatha (earlier Thysanura with families Machilidae and Meinertellidae) are medium-sized, wingless insects with multisegmented antennae, monocondylic mandibles, and mouthparts ventrally projecting which can be partially retracted into the head (Gullan and Cranston 2014). They are found hiding under bark, rock crevices, and litter and mostly feed on algae, lichens, and vegetable debris. Globally, 513 species are known, of them, 11 species belonging to 6 genera and 2 families are distributed in India (Mandal 2010a, b; Chandra 2011; Zhang 2013a, b).

#### **13.1.5.2 Order Zygentoma**

Zygentoma includes medium-sized wingless insects with three long caudal filaments and commonly known as bristletails and silverfish (Sturm 2003). They prefer both humid and dry environments and live freely or as nest associates. Free-living forms usually found in the forest floor or under bark and rocks. Several silverfish species live in association with ant colonies symbiotically (Molero-Baltanas et al. 2017). Globally, 564 species have been described, of which 29 species belonging to 16 genera and 3 families are reported from India (Hazra and Mandal 2007; Zhang 2013a, b).

#### **13.1.5.3 Order Ephemeroptera**

Ephemeroptera (mayflies) are found in all sorts of freshwater habitats (ponds, lakes, streams, rivers, and springs), with few species in the Arctic and hill areas above the tree line. They are susceptible to oxygen depletion, acidification, and various contaminants, including metals, ammonia, and other chemicals in flowing waters (Hubbard and Peters 1978; Moog et al. 1997; Hickey and Clements 1998; Jacobus et al. 2019). Therefore, they are recognized as keystone species and water quality indicators, thus used in biomonitoring (Menetrey et al. 2008). Of 3700 globally described species, 152 species belonging to 60 genera, 15 families, and 4 suborders are distributed in India (Sivaramakrishnan 2016; Selvakumar et al. 2019; Jacobus et al. 2019).

#### **13.1.5.4 Order Odonata**

Odonate larvae live in aquatic environments, and adults remain in a terrestrial environment. The order includes three suborders Zygoptera (damselflies), Anisoptera (dragonflies), and Anisozygoptera (living fossil) (May 2019). Globally

6312 species of odonates are known (Schorr and Paulson 2020), of which 496 species (including subspecies) in 153 genera and 17 families are distributed in India (Subramanian and Babu 2020). Odonates are flagship taxa of freshwater ecosystems and are highly specific to their habitat, therefore frequently utilized as indicator species to evaluate the health of their immediate environment (da Silva Monteiro Jr et al. 2013). They are predators of disease vectors and agricultural pests, and also, their larvae are essential as predators in aquatic ecosystems (May 2019).

### 13.1.5.5 Order Orthoptera

Orthoptera includes devastating pests such as grasshoppers, locusts, and singing insects such as crickets and katydids in two suborders Caelifera and Ensifera (Gullan and Cranston 2014; Song 2018). The global diversity comprises 28,650 valid species (Cigliano et al. 2020), of which 1166 species/subspecies belonging to 449 genera and 22 families are distributed in India (Gupta and Chandra 2019a, b). They are an essential component of grassland fauna in terrestrial ecosystems (Latchininsky et al. 2011). Recently an outbreak of desert locusts, *Schistocerca gregaria* (Forsk.) was found severely damaging crops in Northern India (Joshi et al. 2020). Sound production is a unique and diverse behaviour among Orthopterans and plays a crucial role in reproduction (Robinson and Hall 2002).

### 13.1.5.6 Order Phasmida

Phasmids (=Phasmatodea) are nocturnal, phytophagous, and exopterygote insects and mimic with living or dead twigs and leaves (Bradler and Buckley 2018). They are phytophagous pests of agricultural and timber crops and inhabit tropical, subtropical, and temperate forests, savannas, and grasslands (Baker 2015). Globally, 3350 species have been discovered, of which 140 species belonging to 45 genera and families are distributed in India (Chandra 2011; Zhang 2013a, b; Srinivasan et al. 2018; Brock et al. 2020).

### 13.1.5.7 Order Embioptera

Embioptera (webspinner) are distributed chiefly in tropical and subtropical regions, with few species from the Mediterranean and semi-arid regions (Büsse et al. 2015). They live in small groups, making tunnels in the soil, under stones, and leaf litter and feed on parts of plant origin, preferably dead leaves; some species also feed on mosses and lichens. As their economic or ecological impact on human life is less known, they play a part in the forest recycling system (Poolprasert 2012). Males are mostly winged, whereas females are wingless and gregarious and live in silken tunnel built by them in litter under the bark or soil (Kapur and Kripalani 1957). Globally, 457 species are described (Zhang 2013a, b), of which 32 species belonging

to 6 genera and 2 families (Embiidae, 3 genera, 12 species; Oligotomidae, 3 genera, 20 species) are known from India (Ross 1950; Chandra and Dawn 2014; Gupta et al. 2019).

### 13.1.5.8 Order Plecoptera

Plecopterans (stoneflies) are soft-bodied insects with their adults having two pairs of unequal wings with complex venation. They live in and around water streams of cold temperate climate, representing about 10% of the invertebrate fauna of rocky streams (Thorpe and Rogers 2015). The larval forms are strictly aquatic, dwell under stones in running water streams with high oxygen, and feed upon aquatic flora, whereas adults are terrestrial. Some of the families are commonly named based on their habitat: Pteronarcyidae (salmonflies), Peltoperlidae (roach flies), Perlodidae (springflies and stripetails), Chloroperlidae (sallflies), Taeniopterygidae (winter stoneflies), Capniidae (snow stoneflies), Leuctridae (needle flies), and Nemouridae (forestflies) (Kondratieff 2008). Stoneflies are represented by 3700 species in 16 families (DeWalt et al. 2019). From India, 146 valid species belonging to 27 genera under 8 families, nearly 3.9% of their global diversity and 29.1% of species diversity in Asia-Tropical, including 90 endemic species, have been reported so far (Chandra et al. 2019b).

### 13.1.5.9 Order Dermaptera

Dermaptera (earwigs) are nocturnal and found in soil, under tree barks, stones, and bricks and are associated with warm, somewhat humid, climates (Hass 2018). They feed on dead and decayed organic matter as scavengers. Some feed upon living plant tissues, and some are carnivorous on other arthropods. They are spread worldwide with maximum diversity in tropical and subtropical regions (Naegle et al. 2016). Globally, 2375 valid species in 311 genera and 19 families have been described (Hopkins et al. 2020), of which 284 species belonging to 72 genera and 7 families are distributed in India (Srivastava 2013; Chandra et al. 2019c).

### 13.1.5.10 Order Mantodea

Mantodea (praying mantis) is a well-known group of fascinating and predatory insects, recognizable by their mobile triangular head and large raised raptorial forelegs for seizing prey (Loxton and Nicholls 1979). Globally, 3049 species in 639 genera and 33 families have been described (Otte et al. 2020), of which 184 belong to 73 genera and 11 families (Chandra 2011; Mukherjee et al. 2014; Ghate et al. 2020). They are valuable agents of biological pest control (Symondson et al. 2002). The prey species range from flies, crickets, moths, caterpillars, locusts, and many other insects to vertebrates like amphibians, birds, snakes, and lizards (Nyffeler et al.



2017; Valdez 2020). Mantises are well known to catch small birds, especially hummingbirds, as they fly midair (Fisher 1994; Hildebrand 1949). They are the only known insect to kill their prey with their legs (Rivera and Callohuari 2019). There is only a record of *Hierodula patellifera* (Serville), predated on crimson-backed sunbird from India (Browne 1899). Some of the mantises are pollen feeders, wherein pollen of flowering plants as a potential alternative source of food (Beckman and Hurd 2003).

#### 13.1.5.11 Order Blattodea

Cockroaches together with termites form Blattodea (Beccaloni and Eggleton 2011). Globally, Blattodea includes 7779 valid species. Of them, 4837 are cockroaches (Beccaloni 2014) and 2942 are termites (Beccaloni and Eggleton 2011).

Cockroaches are nocturnal and worldwide in distribution except in Antarctica but are most diverse in tropical and subtropical regions. They occur in a wide variety of habitats, from deserts to semi-aquatic environments. However, the most significant numbers of species live in hot, humid forests (Djernaes 2018). They are detritivores and depend on dead plant matter. Indian diversity includes 181 species of cockroaches belonging to 72 genera under 17 subfamilies and 6 families, including 89 endemic species (Gupta and Chandra 2019b).

Termites are social insects and the essential components of the forest ecosystem in tropical and subtropical areas (Eggleton 2000; Shanbhag and Sundararaj 2013). Indian diversity is represented by 295 species in 52 genera with high-level endemism of approximately 177 species. They are well known for their capacity to damage wood and wood products of all kinds. Termites are ecosystem engineers and help in sustaining soil productivity and rehabilitating degraded soils in tropical agroecosystems (Jouquet et al. 2011).

#### 13.1.5.12 Order Psocoptera

Psocopterans (bark lice or booklice) are soft-bodied species that usually live in tree trunks, under barks, and weathered walls and primarily feed on starch grains and bookbinding glue (Green and Turner 2004) and also on microepiphytes (fungi, algae, and lichens) and general debris (Thornton 1985). Economically, they are essential commodities, and high moisture and mold contamination encourage psocid infestation (Semple 1986). Some psocids are a pest of stored grain (Stejskal et al. 2015); others cause considerable loss to libraries and books. They also help in decomposition by feeding on detritus; the nymph of some form are wood-boring (Smithers 1995). Globally, 5611 species have been described (Johnson et al. 2020; Zhang 2013a, b), of which 126 species are distributed in India.

### 13.1.5.13 Order Phthiraptera

Phthirapterans (chewing and sucking lice) are obligatory ectoparasites, infesting warm-blooded hosts like birds and mammals. This order includes four suborders, namely, Anoplura, Rhynchophthirina, Ischnocera, and Amblycera. Anoplurans are obligatory ectoparasites of mammals, except for Chiroptera, Edentata, Pholidota, Cetacea, Proboscidea, and Sirenia (Kim and Ludwig 2008). Approximately 65% of species of mammals are believed to harbor sucking lice (Adhikary and Ghosh 1994). The chewing or biting lice in the other three suborders are host-specific and sensitive to the temperature having a narrow range of preference (Ash 1960). Globally about 5316 species have been described, of which 466 (16 endemics to India) species are known from India (Galloway 2018; Chandra 2011).

### 13.1.5.14 Order Thysanoptera

Thysanoptera (thrips) are among the smallest (1.5–3 mm) of the winged insects. They are an economically significant group and cause plant galls and leaf rolls, thus reducing seed production and disfiguring leaves, flowers, and fruits. Some transmit plant viruses, a few preys on destructive mites and scale insects, and many of them may support the pollination of flowers (Mound 2018). Globally 6288 species have been described so far (Thrips Wiki 2020), of which 754 species in 260 genera are distributed in India (Tyagi and Kumar 2016).

### 13.1.5.15 Order Hemiptera

Hemiptera comprises four suborders, Auchenorrhyncha (cicadas, leafhoppers, treehoppers, planthoppers, and spittlebugs), Sternorrhyncha (aphids, whiteflies, and scale insects), Coleorrhyncha (moss or beetle bugs; not recorded in India), and Heteroptera (true bugs) (Henry 2017). They are hemimetabolous, some feed on plants (some are serious pests), some are predators, and some are hematophagous. Generally, they live a terrestrial life, whereas some species adapted to an aquatic environment. Auchenorrhynchans are exclusively terrestrial, but infra-orders Gerromorpha and Nepomorpha (in Heteroptera) are aquatic and semi-aquatic and inhabit freshwater or brackish and sea waters (*Halobates* spp.). Globally 107,180 species of this order are known with maximum diversity in Heteroptera (45,254 species) (Henry 2017), followed by comprising of Sternorrhyncha (18,690 species) (Hardy 2018), Auchenorrhyncha (43,204 species), and Coleorrhyncha (30 species) (Bartlett et al. 2018). A total of 6479 species represent Indian diversity in 92 families (Chandra et al. 2018c).

#### 13.1.5.16 Order Hymenoptera

The members of this order may be parasitic or nonparasitic, carnivorous, phytophagous, or omnivorous and are perhaps the most beneficial to human beings as pollinators of flowering plants, producers of wax and honey, and parasites of destructive insects, as well as the best-known members of the social insects—ants, bees, and wasps. Hymenoptera is divided into two suborders, Symphyta (sawflies) and Apocrita, later subdivided into “Aculeata” (stinging wasps, bees, and ants) and Parasitica (parasitoids). The main diagnostic characteristics of Hymenoptera are membranous wings with reduced venation mostly; both fore and hind wings are coupled by means of hooks (hamuli); mouthparts adapted for biting or chewing or modified for sucking also; and ovipositor in females is well developed and variously modified for sawing, piercing or stinging, and egg-laying. As holometabolous insects, the lifecycle comprises egg, larval, pupal, and adult stages. The global diversity of hymenopteran fauna is about 154,067 species (Zhang 2013a, b), of which approximately 10,605 species are known from India (Chandra et al. 2018a).

#### 13.1.5.17 Order Strepsiptera

Strepsiptera (twisted-winged parasitoids) comprises holometabolous insects, which are obligate entomophagous endoparasitoids. Adults have a highly specialized morphology, extreme sexual dimorphism, and unique biology and spend most of their lifecycles as internal parasites of other insects. Globally 627 species in 15 families (Kathirithamby 2018; Cook 2019) are known, of which 28 species (4.5%) are distributed in India (Chandra 2011; Cook 2019).

#### 13.1.5.18 Order Coleoptera

Coleoptera is the most species-rich order on this planet. This much diversity is the outcome of some 250 million years of evolution since the earliest beetle fossils found in the Permian period. The beetles are present virtually in every habitat (except sea and polar regions), including freshwater and coastal habitats; on vegetative foliage such as trees and their bark, flowers, leaves, and underground near roots; and even inside plants in galls, including dead or decaying ones (Gullan and Cranston 2014). In the ecosystem, they immensely perform several ecological and functional roles. The species in this order are of great commercial significance and are both beneficial and harmful to humankind. They are serious pests of various agricultural and forest crops and also act as biological control agents like ladybird beetles (Coccinellidae) and dung beetles (Scarabaeidae).

Exploration of beetle fauna is not equal in every part of the globe, so a higher number of species are expected as this is the most diversified insect order. Grove and Stork (2000) hypothesized that about 70–95% of all the beetle species are yet to be

discovered and described and also emphasized that it would take 200 years to explore the entire beetle fauna of the world. As per estimate made by Zhang (2013a, b), around 386,755 extant species belonging to 29,595 genera and 176 families under four suborders (Archostemata, Myxophaga, Adepfaga, and Polyphaga) are known globally (Bouchard et al. 2017). From India, more than 22,334 species are known in 114 families (Chandra et al. 2018a, b). Seven families are highly diverse—Staphylinidae, Scarabaeidae, Carabidae, Chrysomelidae, Curculionidae, Elateridae, and Tenebrionidae.

### 13.1.5.19 Orders Neuroptera, Megaloptera, and Raphidioptera

Orders Neuroptera (antlions, dusty wings, lacewings, mantidflies, owlflies), Megaloptera (alderflies, dobsonflies), and Raphidioptera (snakeflies) together comprise superorder Neuropterida (Aspöck 2002; Whiting 2002b; Wiegmann et al. 2009; Winterton et al. 2010, 2018). The larvae are terrestrial or aquatic or predaceous or parasitic. Neuropterida, with a total of 6556 species worldwide, are primitive insects with complete metamorphosis. There are 5917 species of Neuroptera, 386 species of Megaloptera, and 253 species of Raphidioptera known globally, of which 327 species of Neuroptera, 30 species of Megaloptera, and 5 species Raphidioptera are distributed in India (Aspöck 2002; Chandra 2011; Zhang 2013a, b; Oswald 2020). Most members are exceptionally predaceous insects; only a few species have been of practical use in the biological control of agricultural insect pests such as aphids, coccids, thrips, moths, and mites.

### 13.1.5.20 Order Trichoptera

Trichoptera (caddisflies) comprises a group of holometabolous insects that are closely related to the order Lepidoptera. The juvenile stages remain dependent on the aquatic environment. They are generally plentiful in freshwater ecosystems such as springs, mountain streams, rivers, the splash zones of waterfalls and marshy wetlands, along shorelines as well as in the depth of lakes, and temporary waters. The caddisflies are considered to be excellent bioindicators of windstorm activity, hydromorphological degradation, and temperature changes (Kalaninová et al. 2014). With a high diversity of species having both cases- and shelter-constructing larvae, they act as useful indicators of organic pollution. Immature stages of caddisflies have been used extensively in biomonitoring assays with indicator species, selected communities or assemblages of species, or more broadly based family level identification of species being used to assess the health status of aquatic ecosystems. Globally, 16,266 species belonging to 632 genera and 63 families (Morse 2020) are known, of which 1299 species belonging to 97 genera and 27 families have been recorded from India (Kaur and Pandher 2020; Pandher et al. 2021).

### 13.1.5.21 Order Lepidoptera

Lepidopterans include primarily phytophagous and most visually appealing insects, butterflies, and moths (Gullan and Cranston 2014). Butterflies represent 18,768 species belonging to 1815 genera in the superfamily Papilionoidea, further divided into six families—Papilionidae, HesperIIDae, Pieridae, Riodinidae, Nymphalidae, and Lycaenidae (van Nieukerken et al. 2011; Zhang 2013a, b). From India, 1501 species of butterflies are reported (Kunte 2000). They are economically significant and serve as pollinators and are appreciated for their aesthetic value (Chakravarthy et al. 1997). They are also good indicators of anthropogenic disturbance and habitat quality as they are sensitive to changes in the environment (Sparrow et al. 1994).

Although moths (139,655 species) contribute about 88% of the total Lepidoptera, they are still less popular, probably due to their predominantly nocturnal habit and drab color, of which 12,193 species (8.8% of global diversity; ZSI) are from India. Moths are considered to be very sensitive to vegetation alterations and climate change, thereby making it essential taxa for monitoring climate and habitat changes, which is an urgent need of the hour to conserve the world's biodiversity. As there is enough evidence of climate change, baseline data preparation is the first step for knowing about the region's floral, faunal, or habitat diversity.

### 13.1.5.22 Order Diptera

Diptera includes two-winged flies, such as midges, gnats, mosquitoes, horse flies, black flies, fruit flies, and house flies. They play significant roles in pollination, as pests of various agricultural and forest crops, as agents of disease transmission and biological control, as invasive alien species, and as scavengers and decomposers. They are worldwide in distribution, even in Antarctica and in practically every habitat except the open sea and inside glaciers (Courtney et al. 2017). With over 157,971 described species globally, they are next to Coleoptera and Lepidoptera in insect diversity (Courtney et al. 2009, 2017). More than 7382 species belonging to 1345 genera are known to be from India, with 30.2% (2183 species) endemism at the species level and 8.31% (110 genera) endemism at the generic level (Banerjee et al. 2018, 2022).

### 13.1.5.23 Order Siphonaptera

The order Siphonaptera (fleas) are hematophagous parasites of birds and mammals—including human beings. Roughly 94% of the species are associated with mammalian hosts, and the remaining species are infesting birds (Whiting et al. 2008). Adult fleas must feed on their host's blood for egg production so that they can maintain a free existence for a considerable length of time when in search of a host. Fleas are the principal pests of humans and domestic animals and vectors of

disease. Globally about 2575 species and subspecies are currently placed in 16 families and 246 genera (Lewis 1998; Whiting et al. 2008). Indian diversity includes 51 species and subspecies belonging to 8 families and 24 genera (Sharma and Chandra 2013; Chandra et al. 2018a, d).

### 13.1.5.24 Order Mecoptera

Mecoptera (scorpionflies) are holometabolous insects having the male ninth abdominal segment (genital segment) in the family Panorpidae upturned and enlarged, protruding like stingers of a scorpion (Whiting 2002a, b). The mecopterans in the family Bittacidae are also known as hanging flies because some species of the genus *Bittacus* hang from the vegetation with the help of their fore and mid legs (Whiting 2002a, b). Globally 737 described species in 9 families and 382 genera worldwide (Bicha 2018) are known, of which 23 species belonging to 2 genera and 2 families (Bittacidae and Panorpidae) are distributed in India (Penny and Byers 1979; Chandra 2004).

## 13.2 Insect Biodiversity in Ecosystems and Biogeographic Zones

### 13.2.1 Aquatic Ecosystem

#### 13.2.1.1 Freshwater

Freshwater habitats cover less than 1% of Earth's surface, and India has 4% of the world's freshwater resources. They include lakes and ponds, rivers, streams, springs, wetlands, etc. The National Wetland Inventory and Assessment by the Ministry of Environment Forest and Climate Change, Government of India, estimates that 10.56 million hectares of inland wetlands exist in India, comprising 6.62 million hectares of natural wetlands and 3.94 million hectares of human-made wetlands. The global freshwater biodiversity includes over 140,000 faunal species as per global assessment of the biodiversity of freshwater ecosystems.

In India, 9456 freshwater animal species are known; of them, phylum Arthropoda alone represents 5923 species or about 62.6% of the total (Chandra et al. 2017). Insect diversity in Indian freshwater includes more than 5014 species/subspecies in 9 major groups (Tables 13.2 and 13.3): aquatic Diptera (1588), caddisflies (1299), beetles (776), dragon and damselflies (494), aquatic bugs (325), mayflies (152), stoneflies (146), Hymenoptera (150), and Lepidoptera (moths: 80). The diversity in these ecosystems is severely affected by overexploitation, water pollution, flow

**Table 13.3** Insect diversity (Arthropoda: Hexapoda) at ecosystem and biogeographic level in India

Classes/orders	Freshwater	Soil	Mangrove	Medical and veterinary	Island	Trans-Himalaya	Himalayas	Desert
Collembola	–	345	28	–	18	30	147	16
Protura	–	20	–	–	–	–	–	–
Diplura	–	19	–	–	–	–	2	–
Insecta								
Archaeognatha	–	11	2	–	2	1	9	–
Zygentoma	–	29	3	–	1	–	17	3
Ephemeroptera	154	–	–	–	3	13	49	1
Odonata	496	–	47	–	78	47	257	58
Orthoptera	–	541	48	–	115	24	497	130
Phasmida	–	140	1	–	11	1	37	–
Embioptera	–	32	–	–	2	1	7	–
Plecoptera	146	–	–	–	–	15	89	–
Dermaptera	–	284	10	–	25	7	152	5
Mantodea	–	–	8	–	12	4	65	16
Blattodea (cockroaches)	–	181	5	181	16	3	44	6
Blattodea (termites)	–	295	15	–	36	–	115	47
Psocoptera	–	–	1	–	–	7	40	–
Phthiraptera	–	–	2	466	4	46	130	53
Thysanoptera	–	–	2	–	32	88	222	30
Hemiptera	325	–	168	–	407	648	1841	143
Hymenoptera	150	2952	172	–	367	585	3054	246
Coleoptera	776	8862	340	6	936	93	10,533	326
Strepsiptera	–	–	–	–	–	–	3	–
Neuroptera	–	–	7	–	15	1	124	17
Megaloptera	–	–	–	–	–	–	14	–

(continued)

Table 13.3 (continued)

Classes/orders	Freshwater	Soil	Mangrove	Medical and veterinary	Island	Trans-Himalaya	Himalayas	Desert
Raphidioptera	–	–	–	–	–	–	1	–
Trichoptera	1299	–	–	–	21	170	425	1
Lepidoptera (butterflies)	–	–	143	–	301	90	1249	138
Lepidoptera (moth)	80	–	200	–	796	190	4195	161
Diptera	1588	–	259	1614	372	213	1698	183
Siphonoptera	–	–	–	51	2	14	38	–
Mecoptera	–	–	–	–	–	–	10	–
Total	5014	13,711	1461	2317	3572	2291	25,064	1580



modification, destruction or degradation of habitat, invasion by exotic species, and hydropower (Gatti 2016).

### 13.2.1.2 Marine (Coastal)

Because of low concentrations of calcium in seawater, insects' diversity in marine habitats is limited, and they failed to establish themselves in the world's seas and oceans (Cheng 1976). As per Cheng (1976), there are no marine insects that remain submerged throughout their lives. Marine water striders in the genera *Halobates* spp. (ten species; Andersen and Foster 1992; Radhakrishnan and Thirumalai 2004), *Halovelia* spp., *Hermatobates* spp., and *Asclepios* spp. have been reported from India and the Indian ocean (Cheng 1976). Apterygote genus *Oudemansia* sp. (Collembola) and dipteran genus *Culicoides* spp. have also been recorded from India marine waters (Sen and Das Gupta 1959; Cheng 1976).

## 13.3 Soil (Belowground)

A large portion of our faunal communities remains below-ground, and the activities of these diverse soil-dwelling organisms and their interaction with the abiotic environment affect the structure and functioning of the soil ecosystem (Wardle et al. 2004). Interactions between soil-dwelling organisms and plants affect plant growth and diversity and thus are considered as the root of sustainable agriculture (Neher and Barbercheck 2019). As per estimates, in India, over 13,711 insect species depend directly or indirectly on the soil ecosystem, comprising 60% of the overall soil faunal diversity of the country (22,586 species) (Chandra et al. 2019e, 2020c) (Tables 13.2 and 13.3). Springtails, proturans, diplurans, beetles, bugs, ants, termites, and crickets are ubiquitous among the soil microarthropods (Table 13.3).

## 13.4 Mangrove Forests

Mangrove forests grow under an environment of high salinity, extreme tides, strong winds, high temperatures, and muddy and anaerobic soils (Kathiresan and Bingham 2001). They are among the world's most productive ecosystems and include a plant community of trees, bushes, and shrubs which grow within the inter-tidal zones of the coastal estuary and riverine areas, between the level of high water of spring tides and a level close to but above mean sea level (Macnae 1968; Rajpar and Zakaria 2014). They have a vital ecological role in protecting the land shores from wind, waves, and flow (Veenakumari and Prashanth 2009). This ecosystem is severely

threatened by urbanization and the expansion of agricultural and aquacultural practices.

The mangroves are stretched along the coastline of 12 states and union territories and are classified into 3 major zones: Eastern Coast Mangroves, Western Coast Mangroves, and Insular Mangroves (Andaman and Nicobar Islands) with 46 true mangrove plant species (Ragavan et al. 2016; Mandal and Naskar 2008). A total of 4822 faunal species belonging to 21 phyla have been recorded from these ecosystems in India (Chandra et al. 2019a), of which 30.3% (1461 species) belong to different insect groups (Tables 13.2 and 13.3). Along with other faunal groups, insects also play indispensable roles in the ecology and contribute to the unique nature of these habitats (Kathiresan and Bingham 2001). Insects are associated with the mangals as permanent residents or only as transient visitors (Kathiresan and Bingham 2001).

## 13.5 Biogeographic Zones

### 13.5.1 *Himalayan Ecosystems*

The Himalayas covers ~6.4% (210,662 sq. km.) of India's broad geographical area, forming the group of mountain ranges lying south of the Great Himalaya and the Siwalik Ranges and Lesser Himalayan Ranges. The Himalayas is broadly classified into four regions Northwest, West, Central, and East Himalayas. Parts of Himachal Pradesh and Jammu and Kashmir come under Northwest Himalaya, Uttarakhand and some area of Himachal under West Himalaya, hills of Darjeeling (West Bengal) and Sikkim under Central Himalaya, and the state of Arunachal Pradesh under East Himalaya.

Insect diversity in this region represents over 81% (25,064 species) of the total Himalayan faunal diversity (30,615 species) and 37.9% of the total insect diversity of India (Chandra et al. 2018a; Chandra et al. 2020a). Central Himalaya has the highest insect diversity with 12,053 species/subspecies, followed by West Himalaya (10,002), Northwest Himalaya (6445), and East Himalaya (3819) (Chandra et al. 2018a). The maximum number of species is reported in the order Coleoptera (10,533 species/subspecies), followed by Lepidoptera (5444: 1249 butterflies; 4195 moths), Hymenoptera (3054), Diptera (1698), Hemiptera (1841), Orthoptera (454), Trichoptera (425), Odonata (257), Thysanoptera (222), Blattodea (159: 115 termites, 44 cockroaches), Dermaptera (152), Phthiraptera (130), Neuroptera (124), Plecoptera (89), Mantodea (65), Ephemeroptera (49), Psocoptera (40), Siphonaptera (38), Phasmida (37), Zygentoma (17), Megaloptera (14), Mecoptera (10), and less than 10 species of Archaeognatha (9), Embioptera (7), and Strepsiptera (3).

### ***13.5.2 Trans-Himalaya (Cold Desert)***

Trans-Himalaya is the high-altitude cold desert and arid mountain areas in the districts of Ladakh and Kargil (Jammu and Kashmir), Lahaul and Spiti valleys, Pooh tehsil (Himachal Pradesh), small areas in the rain shadows of Nanda Devi range (Uttarakhand), and Kangchenjunga range (Sikkim) (Mehta and Julka 2001). They comprise a complex network of barren mountain ranges, lying in the north of the main Himalayan ranges, and include Zaskar, Ladakh, and Karakoram ranges (Mani 1974a, b). Because of dry and cold climatic conditions, this zone is termed a high-altitude cold desert. Trans-Himalaya in India covers a total area of ~1,84,823 sq. km., accounting for 5.62% of the country's landmass (Rodgers and Panwar 1988; Rodgers et al. 2002), further differentiated into Ladakh Mountains, Tibetan Plateau, and TH-Sikkim (Rodgers et al. 2002). Over 69% (2291 species) of total faunal diversity from Indian Trans-Himalaya (3324 species) include insects in different groups (Chandra et al. 2019f). A total of 1031 species are recorded from Ladakh Mountains, 833 from Trans-Himalaya-Sikkim, and 811 from Tibetan Plateau (Chandra et al. 2020a).

### ***13.5.3 Islands (Andaman and Nicobar Islands)***

The Andaman and Nicobar Islands comprise an arcuate series of more than 572 islands, islets, and rocks, with 8249 sq. km. in the Bay of Bengal with a coastline of 1962 km. This archipelago supports a unique biodiversity due to its geographical position, tropical climate, and long isolation from the Indian subcontinent. Over 11,009 faunal species in 24 different phyla have been documented from these islands (Chandra and Raghunathan 2018). Over 32.4% (3572 species) are insects alone (Chandra et al. 2018b). With only 0.25% of India's geographical area, the islands harbor 5.4% of the country's overall insect diversity.

### ***13.5.4 Thar Desert***

Indian Desert spreads over an area of 215,757 sq. km. in the states of Rajasthan (Thar Desert) and Gujarat (Kachchh), comprising 6.56% of the total landmass of the country. Due to the extreme environment, the Thar Desert is considered a delicate ecosystem. The minor factors can create an imbalance in the ecosystem. The biodiversity in the Thar may not be comparatively rich, but it is unique and constitutes an invaluable stock of rare and resistant germplasm. The database by ZSI suggests that all the dominant invertebrate and vertebrate groups and even microscopic protozoans are found in the region. The animal life in the deserts survives by hiding in the burrows, long tunnels, under stones, plant leaves and

roots, ponds, puddles, and larger reservoirs and lakes. Indian desert includes 1580 species belonging to 947 genera under 16 orders of which Coleoptera (326 species), Lepidoptera (299 species), Hymenoptera (246 species), Diptera (183 species), Hemiptera (143 species), and Orthoptera (130 species) remain the major groups.

## 13.6 Ecosystem Services Provided by Insects

### 13.6.1 Pollination

Pollination is the transfer of pollen among male and female parts of flowers to facilitate fertilization and reproduction. Notwithstanding self-pollination and wind pollination, most agricultural and wild plants depend on animals such as flies, wasps, butterflies, moths, beetles, weevils, thrips, ants, midges, bats, birds, primates, marsupials, rodents, and reptiles for pollination. Among them, bees (Hymenoptera) are the most effective pollinators of cultivated and wild plants (Burkill 1906, 1908; Roubik 1995; Garibaldi et al. 2013; Rader et al. 2016; Matias et al. 2017). As per the assessment report on Pollinator, Pollination, and Food Production by Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services report in 2016, animal pollination contributes to nearly 5–8% of global crop production, with an annual market value of 235–577 billion dollars worldwide (IPBES 2016).

#### 13.6.1.1 Hymenoptera (Bees and Wasps)

Globally, over 20,355 bee species (Hymenoptera: Apoidea) are known (Ascher and Pickering 2019), of which 766 species are distributed in India (Saini and Chandra 2019). Many bees are pollen specialists on particular kinds of flowers. Even among generalists, different types of bees have different but strong preferences. Bee species specialize in the collection of pollen and nectar and have a direct relation to floral morphology. Previously, the main focus has been on domesticated bees such as *Apis mellifera* Linnaeus 1758, and *Apis cerana* Fabricius 1793, with some bumblebees and stingless bees for pollination potential. Now wild bee pollination has gained more attention, because of the dramatic decrease in honey bee populations due to mite infestations, especially in the north-temperate climates. There are shreds of evidence for various crops for which honey bees are poor pollinators compared to wild bees (Thorp and Loper 1984).

Twenty-eight species of fig wasps (Hymenoptera: Agaonidae) are reported to pollinate 25 species of *Ficus* trees, the tropical forests' keystone species (Shilpa and Santhosh 2019). The potential of orders Hemiptera and Diptera as pollinators is briefly given by Hassan et al. (2019) and Sengupta et al. (2019).



A wild bee (*Bombus* sp.) in the Indian Himalayan Region

### 13.6.1.2 Thrips

Thrips are also reported to pollinate plants such as cacao, sugarbeet, alfalfa, a few legumes, oil palm, and certain flower species of the families Asteraceae, Fabaceae, Rubiaceae, and Solanaceae (Varatharajan et al. 2016; Varatharajan and Rachana 2019).

### 13.6.1.3 Butterflies and Moths

Butterflies are considered to be pollinators of various plants. However, it is believed that they visit flowers less frequently than bees and deposit less pollen per visit for most plant species (Barrios et al. 2016). Some studies on butterflies and moths suggest that these groups carry pollen farther than other insects, and this long-distance pollen transfer could have significant genetic consequences for plants. Singh (2019) identified 67 species of moths in families Sphingidae, Noctuidae, Notodontidae, Geometridae, and Erebidae to be playing an essential role in the pollination of different plant species in the Indian Himalayan Region.

### 13.6.1.4 Beetles

Beetles have also been widely recognized to visit flowers for nectar, pollen, food materials, mating, and oviposition. Corlett (2004) estimated that beetles are the

second largest group of insects after bees, responsible for pollination in the oriental region. The beetles in the suborder Polyphaga visit flowers, and among them, the families such as Scarabaeidae, Mordellidae, Chrysomelidae, Nitidulidae, Staphylinidae, Curculionidae, and Cerambycidae were found to be potential pollinators (Maeto et al. 1995; Das et al. 2019). Armstrong and Drummond (1986) reported that cultivated nutmeg trees (*Myristica fragrans* Houtt) in southern India are pollinated mainly by an anthicid flower beetle, *Formicomus braminus* (Bonadona). Sivadasan and Sabu (1989) found that *Haptoncurina motschulskii* (Reitter) (Nitidulidae) is an effective agent of cantharophily in *Amorphophallus hohenackeri* (Schott) in Southwest India. Devy and Davidar (2003) reported that beetles pollinate all three trees in the family Annonaceae.

### 13.7 Forest Insects

Forests are complex ecosystems that provide valuable products, such as timber, fuelwood, and fiber, and contribute to the resources of rural inhabitants (FAO 2009). They also render several ecosystem services such as habitat for plants and animals, aesthetic landscapes, pollution reduction, biomass production, pollination, seed dispersal, fire regulation and mitigation, pest regulation of native and invading insects, carbon sequestration, livestock forage, resistance to wind storms, and biodiversity that improve quality of life (Kline et al. 2007; Brockerhoff et al. 2017). Insects are a natural and necessary element of healthy forest and habitat provisioning services. Beeson (1941) defined a forest insect as an insect that lives in the forest. Most forest insects are beneficial, help decay dead vegetation, and release nutrients for plants (Morrison et al. 2007). Many are food for wildlife, and some prey on other insects that are harmful to plants keeping pest outbreaks in check (Morrison et al. 2007). The insect diversity in tropical forest is higher in temperate and boreal forests (Nair 2007).

In the case of Indian forest insects, Beeson (1941) carried out the most extensive work to date and studied over ~4300 species. Later a list of ~16,000 species of forest insect with their host plants (~2140 species) from India and adjacent countries was published by Bhasin and Roonwal (1954), Bhasin et al. (1958), and Mathur and Singh (1959, 1960a, b, c, 1961a, b) in nine volumes. Further, Browne (1968) also published an annotated list of Pests and Diseases of Forest Plantation Trees in the British Commonwealth.

A global review of forest pests and diseases (Food and Agriculture Organization of the United States 2009) reported a total of 110 species of insects as serious forest pest of natural, planted, broadleaf, and conifer forests in Asia and the Pacific in five countries: India, China, Mongolia, Thailand, and Indonesia. Coleoptera and Lepidoptera are two major pest orders reported in these areas. These pest species attack trees, causing discoloration of foliage, defoliation, or both, resulting in dead and down trees and visible damage to forests, which, in turn, may reduce the benefits derived from the forest and its products.

- Several beetles feed on forestry plantation wood. Long-horned beetles (Cerambycidae) feed on freshly felled timber with intact bark, and the beetles of the families Ptinidae (Anobiinae), Bostrichidae, Brentidae, and Curculionidae (Scolytinae, Platypodinae) feed on drier wood. Passalidae, Anthribidae, Lucanidae, and Oedemeridae feed on wet and rotten wood. The most dominant families such as Chrysomelidae, Curculionidae, Scarabaeidae (chafers), and Buprestidae feed on leaves. Scarabaeidae (dung beetles), Tenebrionidae, Cucujidae, and Elateridae feed primarily on the matter on the ground and depend on humus and soil. The predacious beetles in families Carabidae, Cicindelidae, Cleridae, Coccinellidae, and Staphylinidae are dominant in Indian forests. Dermestidae feed on keratinous material. Because of a severe infestation of Sal heartwood borer, *Hoplocerambyx spinicornis* (Newman) [Coleoptera], out of 3.5 million infested trees, 1.59 million trees had to be felled and removed from the worst affected Dindori and Mandla Forest Divisions alone in Madhya Pradesh (Prakasam et al. 2020). Four species of beetles—*Sphenoptera aterrима* Kerremans (Buprestidae), *Cryptorhynchus rufescens* Roelofs (Curculionidae), *Platypus biformis* Chapuis (Curculionidae: Platypodinae), and *Polygraphus longifolia* Stebbing and E.P. (Curculionidae: Scolytinae)—caused massive mortality of pine trees in the Morni Hills of Haryana (Singh et al. 2001; Nair 2007). White grubs (Scarabaeidae: Melolonthinae and Rutelinae) cause damage to teak seedlings, neem, pines, sal, and acacias. *Holotrichia consanguinea* Blanchard and *Holotrichia serrata* Fabricius (Coleoptera: Scarabaeidae: Melolonthinae) are common species found in teak nurseries in India (Nair 2007).
- Lepidoptera (moths and butterflies) is second after Coleoptera in terms of damage caused to trees. The adults are short-lived and feed on nectar and other fluids, while caterpillars feed on foliage. *Hyblaea puera* (Cramer) [teak defoliator], *Eutectona machaeralis* Walker [teak skeletonizer], and *Duomitus ceramicus* (Walker) (= *Xyleutes ceramica* Walker) [bee-hole borer] are the principal pests of teak in Asia. Some species of Pyralidae, Gelechiidae, Blastobasidae, and Oecophoridae bore into young shoots, and some species of Cossidae, Hepialidae, and Tineidae bore into branch wood. Indarbelidae and some species of Tineidae feed on bark. Caterpillars of some species of Pyralidae and Eucosmidae feed on seeds and fruits. Nearly 85 species of lepidopterans have been recorded on teak plantation alone (Nair 2007). *Antheraea mylitta* (Drury) (Saturniidae) is an economically important species commonly known as tasar silkworm, known to produce Tussar silk, a kind of wild silk.
- Termite, as a pest, is capable of causing havoc by destroying wood and wooden structures and live trees. Shanbhag et al. (2013) identified 92 that species are wood-destroying termites representing 22 genera in 5 families: Termopsidae, Kalotermitidae, Rhinotermitidae, Stylotermitidae, and Termitidae.
- The major hemipteran families of forestry importance are Cicadidae, Coccidae, Psyllidae, and Tingidae. In the Indian forests, Cicadas are well-known insects feeding on the sap of tender shoots and twigs of trees, and loud noise produced by male cicadas can be recognized. *Gmelina arborea* Roxb. plantations are facing a greater threat from lace bug *Tingis beelsoni* (Drake) (Tingidae), resulting in top

dying of shoots in the tropical forest of Madhya Pradesh (Meshram and Bhowate 2017). *Heteropsylla cubana* Crawford (Psyllidae), an introduced species, caused severe defoliation and extensive damage of young trees *Leucaena leucocephala* (Lam.) in Southern India (FAO 2007). Some of the hemipterans are economically beneficial too, such as *Kerria lacca* (Kerr) (Hemiptera: Kerriidae), native to Asia, which is the primary source of lac, a resin that can be refined into shellac and other products.

- A gall midge, *Asphondylia tectonae* Mani (Diptera: Cecidomyiidae), has been reported to cause stem galls on teak branches (Chavan and Kumar 1998). Grasshoppers and crickets (Orthoptera) are ubiquitous in Indian forests, but their population do not increase in enough numbers to cause severe damage, although sometimes they cause extensive damage to forest tree seedlings in nursery beds.

### 13.8 Medical and Veterinary Insects

Arthropod-related disorders continue to cause significant health problems to humans, domestic animals, and wildlife. The important insect groups of medical and veterinary significance are Blattodea (cockroaches), Phthiraptera (chewing and sucking lice), Hemiptera (bed bugs and kissing bugs), Coleoptera (blister and rove beetles), Diptera (mosquitoes, sandflies, biting midges, black flies, horse flies, glossinid flies, house and stable flies, latrine flies, myiasis-causing flies), Siphonaptera (fleas), and Hymenoptera (wasps, hornets, velvet ants, ants, bees) (Mullen and Durden 2019).

Insects have profoundly influenced humans as vectors for various deadly diseases and known to transmit protozoans, bacteria, viruses, and nematodes. Malaria, dengue, chikungunya, yellow fever, Japanese encephalitis, lymphatic filariasis, and Leishmaniasis are dreadful diseases transmitted by insect vectors. Likewise, live-stock scourges such as bovine babesiosis, bovine theileriosis, scabies, pediculosis, and botfly infestations, all of which are caused or transmitted by arthropods, have greatly influenced animal production and husbandry practices. The influential groups causing insect-borne diseases are given in Table 13.4.

### 13.9 Insects and Food Security (Edible Insects)

In the twenty-first century, efforts are needed to find new and innovative ways of increasing food production to feed the continuously growing population because of the rising cost of animal protein (Payne and van Isterbeeck 2017). Insect consumption is not a new idea in many parts of the world, especially in tropical countries, and expected as a solution for food and feed security in the future (van Huis et al. 2013).



**Table 13.4** Medical and veterinary insects of India

Order/family	Common name	Number of species (approximate)
Order Blattodea	Cockroaches	181
Order Phthiraptera	Sucking lice	466
Order Hemiptera		
Cimicidae	Bed bugs	10
Reduviidae: Triatominae	Kissing bugs	7
Order coleoptera		
Meloidae	Blister beetles	3
Staphylinidae	Rove beetles	3
Order Diptera		
Culicidae	Mosquitoes	404
Psychodidae: Phlebotominae	Sand flies	52
Ceratopogonidae	Biting midges	374
Simuliidae	Black flies	69
Tabanidae	Horse flies	247
Glossinidae	Glossinid flies	1
Muscidae	House and stable flies	276
Faniidae	Latrine flies	4
Calliphoridae	Enteric disease, myiasis	63
Sarcophagidae	Myiasis	126
Order Siphonaptera	Fleas	51
	Total	2337

Insects are healthy and nutritious and plentiful in protein and fats and high in calcium, iron, and zinc. They can be utilized as alternatives to animal proteins such as chicken, pork, beef, and even fish. Moreover, insects already form a traditional part of many regional and national diets (Huis et al. 2013). Jongema (2017) listed more than 2111 edible insect species worldwide. They belong to the following groups: Coleoptera (beetles, often larvae) (659), Lepidoptera (caterpillars) (362), Hymenoptera (wasps, bees, and ants) (321), Orthoptera (crickets, grasshoppers, and locusts) (278), Hemiptera (true bugs) (237), Odonata (dragonflies) (61), Isoptera (termites) (59), Diptera (flies) (37), cockroaches (37), and others (9%) (Jongema 2017).

Out of the total 2111 edible insects globally, 255 species of insects are used as food by different tribes in India (Chakravorty 2014). In India, Coleopterans (34%) are the maximally consumed insects followed by Orthoptera (24%), Hemiptera (17%), Hymenoptera (10%), Odonata (8%), Lepidoptera (4%), Isoptera (2%), and Ephemeroptera (1%) (Chakravorty 2014). Insects are one of the important diets and consumed by various ethnic groups of northeastern states of India, especially among the tribes of Arunachal Pradesh, Assam, Manipur, and Nagaland and to a lesser extent by the tribes of Meghalaya and Mizoram (Shantibala et al. 2014). Sangma et al. (2016) recorded 158 species of insects consumed by ethnic people of

Arunachal Pradesh. In contrast, tribes of Nagaland consume only 42 species. About 81 species of regional insects are utilized in food and therapeutics by the Nyishi tribe of East Kameng and Galo tribe of West Siang in Arunachal Pradesh (Chakravorty et al. 2011). In the ethnic people of Kerala, Tamil Nadu, Madhya Pradesh, and Odisha, entomophagy is relatively much lower, consuming one to five insect species (Chakravorty 2014). A termite species, *Odontotermes formosanus* (Shiraki), is used as food to enhance lactation in women in Kanikaran and Palliyan tribes in South India (Wilsanand 2005).

### 13.10 Invasive Alien Insects

As per International Union for Conservation of Nature and Natural Resources, invasive alien species are exotic species which become established in natural or seminatural ecosystems or habitat and influence and threaten indigenous biological diversity. One-sixth of the global land surface is highly vulnerable to bio-invasion (Early et al. 2016). Invasive alien species are a severe threat to biodiversity, ecosystem services and functions, human livelihoods and health, and regional economy. They affect native species and communities through competition for resources, disease transmission, apparent competition, or pollination disruption (Kenis et al. 2009). National Biodiversity Authority's report on invasive alien species in India by Sandilyan et al. (2018) included 169 species of plants, microbes, fishes, insects, marine mollusks, invertebrates, amphibians, reptiles, birds, and mammals. Out of the total 68 animal species of IASs, 24 species (35.3%) were insects (Sandilyan et al. 2018). As of today, a total of 27 species of insects have been identified as invasive alien in India. The maximum number of invasive species is in Hemiptera (16), followed by Lepidoptera (5), Hymenoptera (3), and Coleoptera (3). A list of invasive alien species is given in Table 13.5.

### 13.11 Threats and Conservation

Habitat loss, deforestation and degradation, agriculture, the encroachment of forest land, grazing, human-wildlife conflict, forest fires, illegal extraction of forest products, commercial plantations, replacement of indigenous species with exotic species, and uncoordinated infrastructure development are among the major threats faced by biodiversity globally and in India (Wilson 1989; Chatterjee et al. 2006). Like other animal groups, insects have also been severely impacted because of habitat loss, invasive alien organisms, environmental contamination, and biological control (Samways 2006). As per estimates, insect biodiversity across the globe is declining

**Table 13.5** List of invasive alien insects of India

S. N.	Order/name of the species	Family	Common name	Year
<i>Hemiptera</i>				
1.	<i>Eriosoma lanigerum</i> (Hausmann)	Aphididae	Woolly apple aphid	1889
2.	<i>Pterochloroides persicae</i> (Cholodkovsky)	Aphididae	Brown peach aphid	2018
3.	<i>Quadraspidiotus perniciosus</i> (Comstock)	Diaspididae	San Jose scale	1911
4.	<i>Insignorthezia insignis</i> (Browne) (= <i>Orthezia insignis</i> Browne)	Ortheziidae	Lantana bug	1915
5.	<i>Icerya purchasi</i> (Maskell)	Margarodidae	Cottony cushion scale	1921
6.	<i>Pineus pini</i> (Macquart)	Adelgidae	Pine woolly aphid	1970
7.	<i>Heteropsylla cubana</i> (Crawford)	Psyllidae	Subabul psyllid/leucaena psyllid	1988
8.	<i>Aleurodicus dispersus</i> (Russell)	Aleyrodidae	Spiraling whitefly	1993
9.	<i>Aleurodicus rugioperculatus</i> (Martin)	Aleyrodidae	Rugose spiraling whitefly	2016
10.	<i>Bemisia tabaci</i> (Gennadius) (= <i>Bemisia argentifolii</i> Bellows and Perring)	Aleyrodidae	Silver leaf whitefly	1999
11.	<i>Paracoccus marginatus</i> (Williams and Granara de Willink)	Pseudococcidae	Papaya mealy bug	2001
12.	<i>Phenacoccus solenopsis</i> (Tinsley)	Pseudococcidae	Cotton mealy bug	2005
13.	<i>Phenacoccus madeirensis</i> (Green)	Pseudococcidae	Madeira mealy bug	–
14.	<i>Pseudococcus jackbeardsleyi</i> (Gimpel and Miller)	Pseudococcidae	Banana mealy bug	–
15.	<i>Aleurothrix floccosus</i> (Maskell)	Aleyrodidae	Woolly whitefly	2019
16.	<i>Aleurotrachelus atratus</i> (Hempel)	Aleyrodidae	Neotropical whitefly	2019
<i>Lepidoptera</i>				
17.	<i>Phthorimaea operculella</i> (Zeller)	Gelechiidae	Potato tuber moth	1937
18.	<i>Plutella xylostella</i> (Linnaeus)	Plutellidae	Diamondback moth	1914
19.	<i>Tuta absoluta</i> (Meyrick)	Gelechiidae	South American tomato leaf miner	2014
20.	<i>Spodoptera frugiperda</i> (Smith)	Noctuidae	Fall armyworm	2018
21.	<i>Citripestis eutraphera</i> (Meyrick)	Pyralidae	Snout moth/mango moth	–
<i>Hymenoptera</i>				
22.	<i>Leptocybe invasa</i> (Fisher and La Salle)	Eulophidae	Blue gum chalcid/eucalyptus gall wasp	2006
23.	<i>Quadrastichus erythrinae</i> (Kim)	Eulophidae	Erythrina gall wasp	2005
24.	<i>Anoplolepis gracilipes</i> (Smith)	Formicidae	Yellow crazy ant	–
<i>Coleoptera</i>				
25.	<i>Hypothenemus hampei</i> (Ferrari)	Scolytidae	Coffee berry borer	1990
<i>Diptera</i>				
26.	<i>Liriomyza trifolii</i> (Burgess)	Agromyzidae	Serpentine leaf miner/American serpentine leaf miner	1990
27.	<i>Stenochironomus nelumbus</i> (Tokunaga)	Chironomidae	Lotus lily midge	2005

Source: Selvaraj et al. (2019), Chalapathi Rao et al. (2018), Sandilyan et al. (2018), Mathew and Habeeburrahman (2008), Bisht and Giri (2019), Singh et al. (2020), and Sundararaj et al. (2020)

dramatically, which may lead to the extinction of 40% of global species (Sánchez-Bayo and Wyckhuys 2019; Didham et al. 2020). Lepidoptera, Hymenoptera, and dung beetles (Coleoptera) appear to be the taxa most affected. Furthermore, four major aquatic orders, Odonata, Plecoptera, Trichoptera, and Ephemeroptera, have already lost a considerable proportion of species (Sánchez-Bayo and Wyckhuys 2019).

The IUCN Red List (August 2020) includes 22 species under the threatened category from India, distributed in Himalaya, Western Ghats, North-East India, and Andaman and Nicobar Islands (Tables 13.6 and 13.7). Eighteen species are Vulnerable, three species are Endangered, and only a single species is Critically Endangered (Table 13.6, IUCN 2020). The group-wise species list of threatened insects from India is given in Table 13.4. A total of 484 species of Indian insects are protected under Indian Wildlife (Protection) Act 1972, covering 444 species of butterflies, 38 beetles, 1 species of dragonfly, and one species of louse.

Thus global warming and climate change are making shifts in the diversity, geographic distribution, and abundance of insects. Long-term monitoring of insect population is required to identify the most affected regions and indications of a biological response to climate change. Zoological Survey of India has started a project to study the impact of climate change of lepidopterous insects in the Indian Himalayan region through long-term monitoring. Moreover, combined DNA sequencing and morphological characterization approaches can solve pest species complexes, therefore helping in the formulation of integrated pest management of crops. When analyzed in contrast with environmental parameters, the collection data present in the museums may also provide future distributional predictions of the pest species.

**Table 13.6** Status of threatened insect species (Critically Endangered, Endangered, and Vulnerable) from the world, South and Southeast Asia, and India as per IUCN Red List (August 2020)

IUCN category	Global	South and Southeast Asia	India
Extinct	63	1	0
Extinct in wild	1	0	0
Critically endangered	336	31	1
Endangered	677	123	3
Vulnerable	806	150	18
Lower risk: Conservation dependent	3	0	0
Near threatened	594	121	19
Least concern	4752	888	307
Data deficient	2561	730	168
	9793	2044	516

**Table 13.7** Checklist of threatened insects known from India as per IUCN Red List (August 2020)

S.N.	Order/name of species	Common name	IUCN category	Distribution
<i>Phlebotominae</i>				
1.	<i>Haematopinus oliveri</i> (Mishra and Singh)	Pygmy hog-sucking louse	Critically endangered	India (Assam)
<i>Orthoptera</i>				
2.	<i>Nicephora subulata</i> (Bolivar)	Palani Hills bush cricket	Vulnerable	India (Tamil Nadu)
<i>Odonata (dragon and damselflies)</i>				
3.	<i>Anisoptera vallei</i> (St. Quentin)	–	Vulnerable	India (Meghalaya, and Nagaland)
4.	<i>Bayadera hyalina</i> (Selys)	–	Vulnerable	India (Meghalaya); Thailand
5.	<i>Coeliccia fraseri</i> (Laidlaw)	–	Vulnerable	India (Meghalaya)
6.	<i>Disparoneura apicalis</i> (Fraser)	Black-tipped bamboo tail	Vulnerable	India (Kerala, Karnataka)
7.	<i>Indosticta deccanensis</i> (Laidlaw)	Saffron reed tail	Vulnerable	India (Kerala, Karnataka)
8.	<i>Libellago andamanensis</i> (Fraser)	Andaman heliodor	Vulnerable	India (Andaman Islands)
9.	<i>Libellago batus</i> (Hämäläinen)	–	Endangered	India (Nicobar Islands)
10.	<i>Protosticta sanguinostigma</i> (Fraser)	Red spot reed tail	Vulnerable	India (Tamil Nadu, Kerala, and Karnataka)
11.	<i>Chlorogomphus xanthoptera</i> (Fraser)	–	Vulnerable	India (Tamil Nadu, Kerala)
12.	<i>Chloropetalia selysi</i> (Fraser)	–	Vulnerable	India (Darjeeling); Nepal
13.	<i>Idionyx galeata</i> (Fraser)	–	Endangered	India (Tamil Nadu, Kerala, Karnataka)
<i>Hymenoptera: Formicidae (ants)</i>				
14.	<i>Monomorium effractor</i> (Bolton)	–	Vulnerable	India (Maharashtra)
15.	<i>Myrmica erepatrix</i> (Bolton)	–	Vulnerable	India (Jammu and Kashmir)
16.	<i>Pheidole lanuginosa</i> (Wilson)	–	Vulnerable	India (Arunachal Pradesh, Assam)
17.	<i>Pheidole parasitica</i> (Wilson)	–	Vulnerable	India (Arunachal Pradesh, Assam, Kerala)
18.	<i>Rhoptromyrmex mayri</i> (Forel)	–	Vulnerable	India (Maharashtra)
<i>Lepidoptera (butterflies)</i>				
19.	<i>Bhutanitis ludlowi</i> (Gabriel)	Mystical Bhutan glory	Endangered	India (Arunachal Pradesh); Bhutan
20.	<i>Euploea andamanensis</i> (Atkinson)	Andaman crow	Vulnerable	India (Nicobar Island and Andaman Island); Myanmar
21.	<i>Euploea scherzeri</i> (Felder)	Cinnamon crow	Vulnerable	India (Nicobar Island and Andaman Island)
22.	<i>Graphium epaminondas</i> (Oberthür)	Andaman swordtail	Vulnerable	India (Nicobar Island and Andaman Island)

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