Chapter 1
Introduction to and Importance of Insects

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1.1 Introduction

Insects and closely related arthropods are the dominant and most diverse forms of terrestrial and aquatic (non-marine) animal life on the planet. Other than marine systems, insects occupy every conceivable environment and habitat on the Earth. Crustaceans and Annelids (worms) are the dominant and most diverse groups of animals in marine systems. The dominance of insects is true in terms of diversity (number of species), numbers of individuals, and total biomass within a given area. As of this writing, there are approximately one million known species of insects (species that have been scientifically described—they have been provided a scientific name and their evolutionary relationship to other species is relatively well established). The known number of insect species is only a fraction of the estimated total number of species. The total number of insect species has been estimated to be between five and ten million species; most of which have yet to be discovered and scientifically described.

When all of the described species on the planet are considered, the number of insect species accounts for more than 50% of the total (Fig. 1.1; Purvis and Hector 2000; Stork 2018). As more species are discovered, the proportion of insects is likely to increase as our knowledge of the biodiversity of other plant and animal species is much more complete. One caveat to the claim of "dominance" is that there are other very poorly described groups with a large number of undescribed species: the prokaryotes (Bacteria and Archaea), many groups of protozoa, as well as the fungi and nematodes. Perhaps, with a better understanding of life's overall diversity, other groups will rival the apparent dominance on Earth by the insects.

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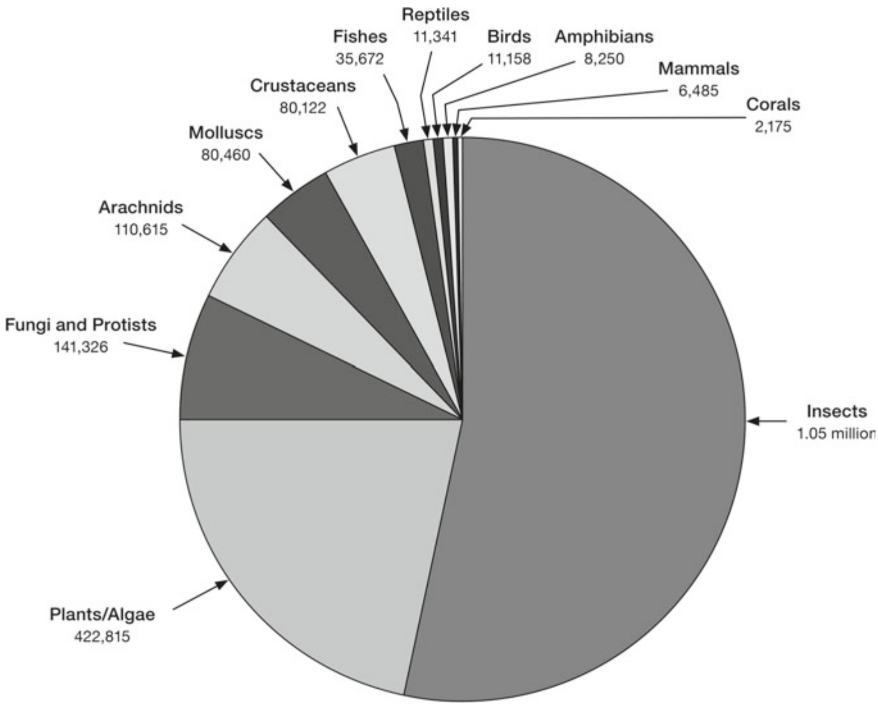

Fig. 1.1 The relative proportions of described species on the planet. © Matt Leatherman

The overwhelming majority of insect species are not harmful to human health, commerce, or agriculture, and in some form or fashion are actually beneficial. Worldwide, less than 1% of all known insect species are pests either destroying/damaging food and fiber resources, stored products, structures, or transmitting diseases. Within forest ecosystems, several insect species are serious pests that threaten our use of these natural resources and the ecosystem services they provide. In short, insects are our greatest competitors for the resources required to sustain our lives. Those few species that are pests result in tremendous efforts to manage their populations and limit the damage they cause. As the impacts of forest pests (especially undergoing outbreak infestations as shown in Fig. 1.8) are exceptionally visible, the value and benefit of most insect species is largely unknown to the general public.

1.2 What Is an Insect?

To fully understand the importance of insects to Earth's ecosystems, one must first understand where insects are placed in the phylogenetic tree of life. All species are placed within one of three large domains: Eukarya, Archaea, and Bacteria. Archaea and Bacteria are referred to as prokaryotic species. They are small (0.5–5 μm) unicellular organisms that lack true nuclei and other membrane covered organelles. Prokaryotic cells typically possess cell walls comprised of predominantly peptidoglycan (Bacteria) or a mix of other polysaccharides and proteins (Archaea). Prokaryotic DNA is not found within a membrane-bound nucleus. The diversity of prokaryotic species is exceedingly large and likely, when fully understood, much greater than any other life form on the planet, including insects. The domain Eukarya contains all other species on the planet and is characterized by possessing numerous membrane-bound organelles including a nucleus containing the cell's DNA. Eukaryotic cells are large (10–100 μm) compared to prokaryotic species and may lack cell walls. If cell walls are present, they are typically made up of primarily of cellulose (e.g. plants) or chitin (e.g. fungi) often mixed with other polysaccharides and glycoproteins. Each Domain is divided into smaller and smaller evolutionarily related groups (=clades) of related species. Each group is defined by shared traits (e.g. All insects possess a head, thorax, abdomen, three pair of legs and usually a pair of wings. All Coleoptera [beetles] possess these same traits and are typically convex in shape with the first set of wings being shell-like and protective; the second set of wings are membranous and held folded under the first set, Fig. 1.2).

This categorization of species is somewhat analogous to a set of Russian nesting dolls; below the level of Domain, in increasing specificity are the categories of Kingdom, Phyla, Class, Order, Family, Genus, and Species. Each Domain encompasses several Kingdoms, each Kingdom encompasses several Phyla, and so forth down to the level of a single species. As species are discovered, they are placed within this classification framework known as the Linnaean system of classification, named for Carolus Linnaeus who first proposed the system in the eighteenth century. Individual species are provided a two-word descriptor: the genus and the specific epithet, both of which are italicized when written (e.g. *Choristoneura fumiferana* (Tortricidae) for the eastern spruce budworm, Fig. 1.3).

Within this classification system, Insects (Class Insecta) are found within the Animal Kingdom and within that, the Phylum Arthropoda. Arthropoda includes not only insects, but also other Classes including Arachnida (spiders, scorpions, ticks,

Fig. 1.2 A beetle known as a firefly, *Photinus pyralis* (Coleoptera: Lampyridae) showing the two sets of wings. The forewings known as elytra are tough and protective, while the hindwings are membranous. © Alex Wild, used by permission

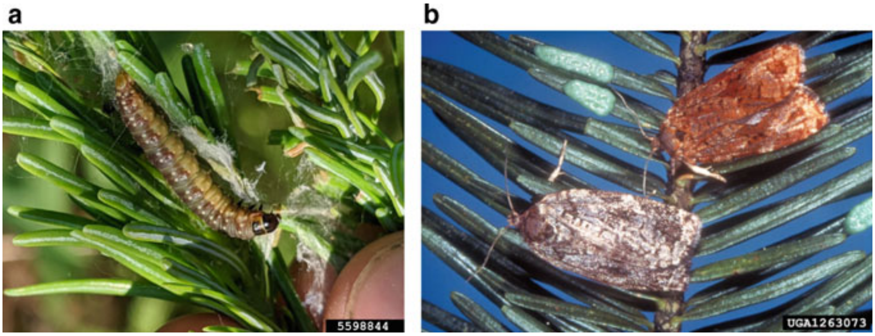

Fig. 1.3 The moth, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). **a** Larval stage. © Neil Thompson, University of Maine at Fort Kent. Bugwood.org; **b** Adults © K. B. Jamieson, Canadian Forest Service, Bugwood.org

mites, and others), Crustacea (crabs, lobsters, shrimp, isopods, copepods, and others), Diplopoda (millipedes), Chilopoda (centipedes), and several other groups. Within the Arthropoda, insects are found in the Subphylum Hexapoda and the Class Insecta. Table 1.1 provides a general classification system for the Arthropoda. It is important to note that any classification system is subject to continual modification as new species are described and a better understanding of evolutionary relationships within and between groups is acquired.

Arthropods are generally described as **bilaterally symmetrical** and **segmented** creatures possessing an **exoskeleton.** The exoskeleton lines the entirety of the outside of the body and almost all of the internal portions of the digestive, excretory, respiratory and reproductive systems. The exoskeleton provides structural support for the animal as well as providing internal and external protection against predators, parasites, physical shock, and desiccation. The segments of the body may have undergone **tagmosis** (fusion) to form distinct body sections or **tagma** (e.g. a head). Internally, the circulatory system of arthropods is an **open system** lacking true veins and arteries—the blood is simply pumped around inside the body cavity by a structure called the **dorsal vessel**. There is no spinal cord; however, there is a **ventral nerve cord** comprised of a pair of ganglia located approximately in each body segment. Ganglia are connected in a chain-like manner by nerves. The foremost ganglion is multi-lobed and is referred to as the brain. The appendages of arthropods are referred to as jointed; "Arthropod" literally means "jointed foot" in Greek. The various classes of animals found within the Arthropoda are variations of the above characteristics. Within the Class Insecta, there are **29** orders of insects (Table 1.2), most of which can be found within forest ecosystems.

Insects are characterized by possessing **three body tagmata** (head, thorax, and abdomen, each of which is the result of tagmosis of multiple segments), **three pair of legs, two pair of wings as adults**, and **one pair of antennae** (Fig. 1.4). Within the class Insecta, there is a tremendous variety in appendages (e.g. antennae, legs and

Table 1.1 General classification system for the extant major groups within the Phylum Arthropoda. The listing below does not include extinct groups

Phylum Arthropoda
Subphylum Chilicerata
Class Arachnida: Spiders, Scorpions, Wind Scorpions, Sun spiders Ticks, Mites
Class Xiphosura: Horseshoe crabs
Class Pycnogonida: Sea Spiders
Subphylum Diplopoda: Millipedes
Subphylum Chilopoda: Centipedes
Subphylum Pauropoda: Pauropods
Subphylum Symphyla: Symphylans
Subphylum Crustacea*: Lobster, Crab, Shrimp, Copepods, Brachiopods, Barnacles, Sea lice
Subphylum Hexapod*
Class Collembola: Springtails
Class Protura: Proturans or Coneheads
Class Diplura: Diplurans
Class Insecta: The Insects

* Currently, many systematists group the Crustaceans and Hexapods into a single group known as the Pancrustacea. The combination of molecular and morphological evidence for doing so is strong. The resulting classification of the these subphyla (Oakley et al. 2013; Rota-Stabelli et al. 2013), as well as the Diplopoda and the Chilopoda is complicated and beyond the scope of this chapter. At this level the reader is urged to simply understand the characteristics that define the class Insecta

wings). These have been modified through evolutionary time for specific functions (Fig. 1.5).

Natatorial legs are oar-like in shape and used for swimming (e.g. water boatmen). Raptorial legs are used for grasping prey (e.g. mantids). Saltatorial legs have evolved for jumping (e.g. grasshoppers). Cursorial legs are used for running (e.g. carpenter ants), and fossorial legs are specialized for digging/burrowing in the soil (e.g. mole crickets). Not all insects may have wings. Juvenile insects lack wings. Almost all adult insect possess wings; however, some species, through the process of evolution, have entirely lost the need for and the ability to develop wings (e.g. fleas, adult worker ants). Insect mouthparts (Fig. 1.6) also show great variation. Mouthparts may be modified for chewing (e.g. beetles among many), sucking plant fluids (e.g. aphids, whiteflies, leafhoppers), sucking blood (mosquitoes), lapping up liquids (e.g. carrion flies), and combinations of the aforementioned (bees).

The possession of an exoskeleton presents several challenges. The exoskeleton cannot grow in the traditional sense; it does not and cannot stretch. During growth in the immature phases, the insect must shed its old exoskeleton and produce a new larger one. This process is called **molting** or **ecdysis** (see Chapter 2). After the old

Table 1.2 List of extant orders of the Class Insecta

Classs Insecta
Order Archaeognatha: Jumping Bristletails
Order Zygentoma: Silverfish and Firebrats
Order Ephemeroptera: Mayflies
Order Odonata: Dragonflies and Damselflies
Order Orthoptera: Grasshoppers, Crickets, Katydids
Order Phasmatodea: Walkingsticks and Leaf insects
Order Embioptera: Webspinners
Order Notoptera: Ice Crawlers, Gladiators
Order Dermaptera: Earwigs
Order Plecoptera: Stoneflies
Order Zoraptera: Angel Insects
Order Mantodea: Mantids
Order Blattodea: Roaches and Termites
Order Psocoptera: Booklice
Order Phthiraptera: Lice
Order Thysanoptera: Thrips
Order Hemiptera: True bugs, Leafhoppers, Aphids, Whiteflies, Psyllids, Scales
Order Coleoptera: Beetles
Order Raphidioptera: Snakeflies
Order Neuroptera: Lacewings and Antlions
Order Megaloptera: Alderflies and Dobsonflies
Order Strepsiptera: Twisted-wing Parasites
Order Trichoptera: Caddisflies
Order Lepidoptera: Butterflies and Moths
Order Siphonaptera: Fleas
Order Mecoptera: Scorpionflies
Order Diptera: Flies
Order Hymenoptera: Bees, Wasps, Ants, and Sawflies

exoskeleton is shed and prior to the hardening of the new exoskeleton, the animal will expand the volume of its body, thus providing new internal space for growth. Ultimately, the new exoskeleton will harden and external growth will cease until the next molt. During this process, with the expansion of the exoskeleton, space is also made available for internal growth of organs. Before the exoskeleton has hardened into a protective shell, the insect is at its most vulnerable to predation, parasistism, disease, and physical shock. The molting process is under tight control by the endocrine system of the insect and only occurs within the juvenile stages of the animal (Fig. 1.7).

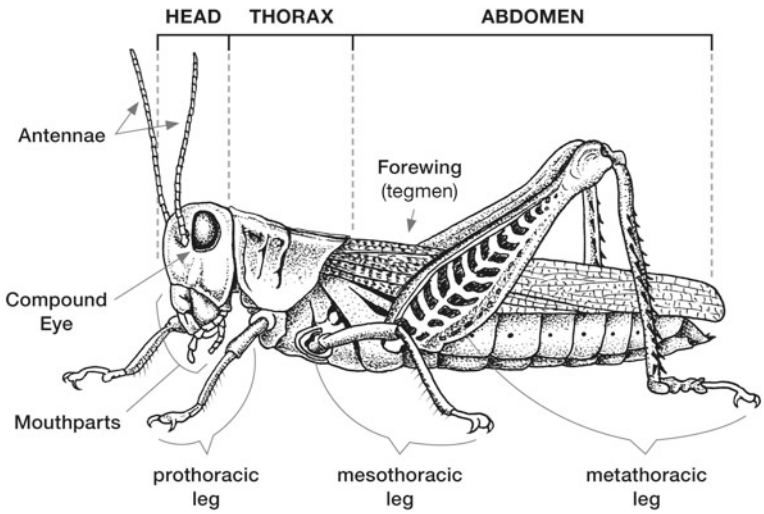

Fig. 1.4 Basic insect body plan. ©MattLeatherman

Once the adult stage is reached, molting and growth cease. Each juvenile stage in the life cycle of an insect is referred to as an instar. The time it takes to develop from one instar to the next is known as a stadium. The number of instars and the length of stadia vary tremendously among the insects. For example, depending on the species, insects may have one, two, or many generations per year (univoltine, bivoltine, and multivoltine, respectively). Conversely, many species will require many years to develop (e.g. several groups of aquatic insects and some wood boring beetles).

As insects are ectotherms ("cold-blooded") the process of growth is also dependent on environmental temperature. Typically, within limits, the warmer the environment is above a species-specific developmental threshold temperature, up to a maximum optimal temperature, the faster growth will occur. Below or above this optimum, growth will be slower. Below the threshold temperature, growth will cease. Temperatures more than a few degrees above the optimum are often fatal. For many species, this relationship between development time and temperature has been accurately quantified. With this information, one can predict the emergence of insect populations—a very useful tool in managing pestiferous species.

1.3 The Importance of Insects

Given the diversity and abundance of insects (and their near relatives), it is not surprising that they play essential and critical roles in the functioning of terrestrial and freshwater ecosystems and provide what are known as ecosystem services (Noriega et al. 2018).

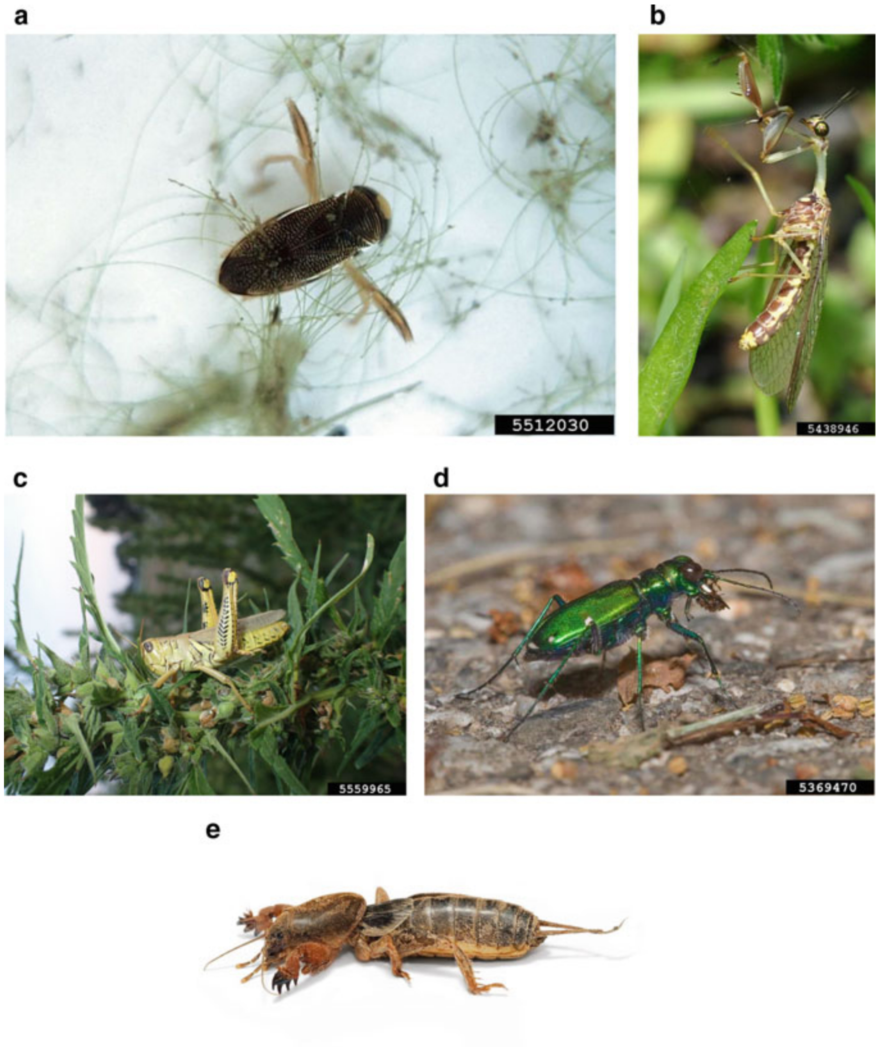

Fig. 1.5 Insect legs. **a** A water boatman showing natatorial legs for swimming. © Kansas Department of Agriculture, Bugwood.org. **b** A mantidfly showing raptorial front legs for grasping prey. © Jon Yuschock, Bugwood.org. **c** Saltatorial rear legs for jumping in a grasshopper. © Whitney Cranshaw, Colorado State Univerisity, Bugwood.org. **d** a tiger beetle showing cursorial legs for running. © Susan Ellis, Bugwood.org. **e** Fossorial legs for digging in a mole cricket. ©Fir0002/Fflagstaffotos under GFDL

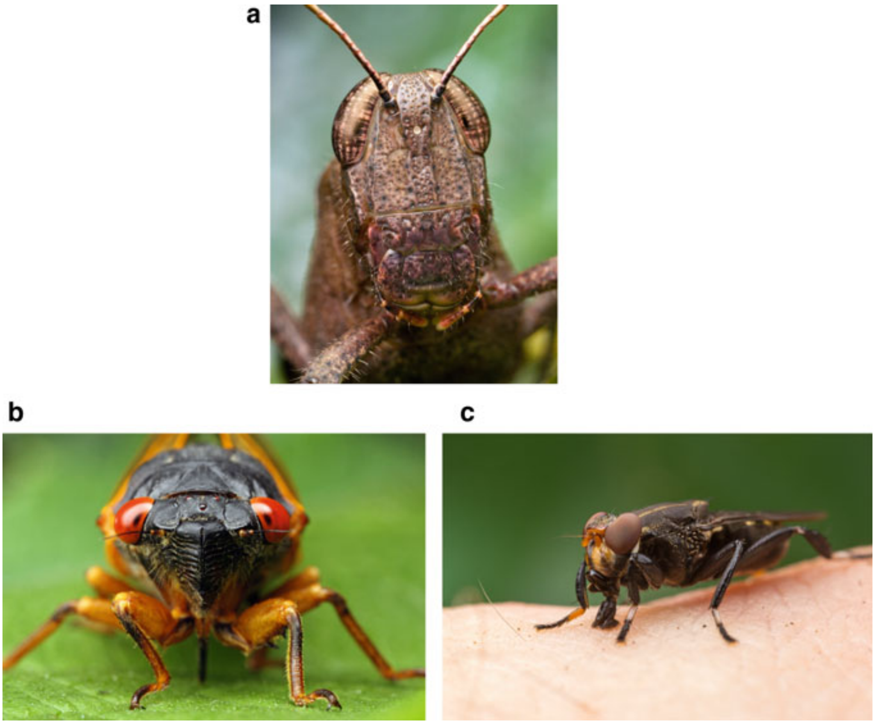

Fig. 1.6 Most common insect mouthparts. **a** Chewing (grasshopper. ©Alex Wild, used by permission), **b** Piercing-Sucking (periodical cicada, ©Alex Wild, used by permission), **c** Sponging-lapping (fly, Ropalomeridae: Diptera. ©Alex Wild, used by permission)

Fig. 1.7 A periodical cicada, *Magicicada* (Hemiptera: Cicadidae) undergoing a molt. © Alex Wild, used by permission

1.3.1 Decomposition, Nutrient Recycling, and Soil Formation

As organisms release waste products or die, they ultimately leave behind an abundance of organic material that can be used by other organisms as both energy and nutrient resources. Species that specialize on feeding on dead organisms and waste products are known as decomposers and/or detritivores (detritus is simply dead organic material). Detritivores are critical in physically and chemically breaking down and recycling organic material such that it can be, in turn, used by other organisms or returned to the abiotic environment. Indeed, much of the inorganic nutrients required by plants are derived by the decomposition of dead organisms. Similarly, all species occupying trophic levels which are dependent on plants for energy, nutrients and habitats, are indirectly supported by the recycling activities of detritivores. The processes of decomposition are complex. In short, it is a step-wise series of processes, by which dead organic material (a dead animal body or a fallen tree) is sequentially broken down into smaller and simpler particles, which are utilized by a succession of species, each specializing on a particular particle size with a particular nutrient value for that species.

In forest ecosystems, decomposition is critical in breaking down and recycling the complex macromolecules (cellulose, lignins, hemicellulose, etc.) found in plant cell walls. This is especially critical for the woody portions of the plant. As this material is broken down, it forms smaller and smaller particles of organic matter which are then utilized as sources of nutrition by additional species of decomposers. With respect to the role of insects, the process of plant decomposition starts with herbivorous insects feeding on the live structures of plants. During the process of ingestion and digestion, the plant material is physically and chemically broken down. The herbivore will absorb necessary nutrients from this material, metabolize organic compounds as sources of energy, and then will expel as waste undigestible/unused material. This expelled material (referred to as *frass*) is often still rich in organic and inorganic nutrients which, in turn, are utilized by additional organisms (including, ultimately, plants). CO_2 generated through metabolism is released during respiration into the atmosphere. As a result of the damage inflicted by herbivores, the plant is subject to additional attack by other organisms including herbivores that may accelerate both plant death and decomposition (other insects, fungi, prokaryotes). Often attack by one species leads to subsequent attack by others.

Decomposition need not start with a live plant and the breakdown of woody material often begins with plant death. Here, the material is initially attacked by a variety of species (e.g. termites, beetles) that have evolved symbiotic associations with microorganisms which allow them to digest cellulose. While feeding these wood-feeding (xylophagous) species tunnel into their food resource, opening it up for further feeding and decomposition by additional species.

Insects also play a role in the decomposition of animals. Once dead, vertebrate animals are subject to being fed upon by both other vertebrates (carrion feeders) as well as insects. Like plants, decomposition in animals follows a series of overlapping stages. Typically, the first insects that infest an animal corpse are evolutionarily specialized fly species (Order Diptera). Adult female flies responding to volatile cues will lay eggs on an animal corpse. The eggs hatch, and the developing larvae burrow into and feed on the dead animal tissues. This feeding opens the corpse up to inoculation and subsequent decomposition by a variety of microorganisms and prokaryotes. Subsequent to the initial feeding by flies, the physical and chemical properties of the carrion render it susceptible to colonization by a variety of beetle species (Coleoptera). As with plant decomposition, although the stages of animal decomposition are not distinct, each species of insect has its preferred type and quality of tissue on which to feed and develop.

The decomposition of both plants and animals attracts suites of predatory and parasitic insects and other arthropods that specialize on the insects engaged in decomposition. In both cases, there is a unique environment supporting insects that feed upon dead tissues while being fed upon by insect predators and parasites. Ultimately, with the decomposition of both plants and animals, microorganisms and prokaryotes break the remaining biological material down to simple organic and inorganic chemical constituents.

Linked to the process of decomposition is that of soil formation. Soil structure, texture, nutrient content, and water holding capacity are all emergent properties of a variety of factors including climate, parent material of the underlying bedrock, topography, the organisms associated with the soil, and time. Decomposition, and the roles that insects play in that ecological process, are responsible for much of the organic matter found in soil. The importance of fine-grained organic matter as a component of soil is critical to all of the aforementioned properties of soil that are necessary for supporting the diversity of terrestrial life on the planet (Jackson et al. 2017; Lehmann and Kleber 2015; Obalum et al. 2017).

1.3.2 Ecological Roles and Interactions

Like the diversity of the Class Insecta, the ecological roles that insects play in the Earth's ecosystems and interactions that insects are involved in are similarly diverse. Insects occupy virtually every ecological role in the planet's terrestrial ecosystems with the exception of being photosynthetic producers. As life on the planet relies on energy provided by the sun, from an ecological perspective, photosynthetic producers form the critical link between this ultimate source of energy and the rest of the organisms on the planet via a complex network of food webs (Schlesinger and Bernhardt 2020), exceptions being unique isolated systems that are reliant on deep ocean thermal vents for energy. Photosynthesis captures the energy from the Sun using carbon dioxide from the atmosphere and water to form a variety of energy rich compounds [e.g. carbohydrates, lipids, and proteins (using nitrogen sources extracted from the soil)] that form the fundamental building block for plants and are stored within plant cells. Thus, producers form the base of any food web. Above the level of producers are the herbivores—animals that feed on plants. Herbivores, consequently, are the first step in redistributing "captured energy" and nutrients to the rest of the living portions of any ecosystem. As a variety of animals consume herbivores and are in turn consumed themselves, captured solar energy and plant-derived resources are ultimately distributed through an ecosystem via complex food webs. Insects are the dominant set of herbivores (~25% of insect species are herbivores) and thus form the critical energy and nutrient linkages between plants and the rest of animal life.

As a group, insect herbivores feed on all parts and structures of plants (roots, stems, reproductive structures, etc.). Indeed, all parts of every terrestrial and freshwater aquatic plant are likely to be fed upon by at least one insect herbivore. There are a wide variety of types of insect herbivores and most can be categorized by the plant tissues on which they feed. Folivores are adapted to feed on the leafy components of the plant. Frugivores specialize upon fruit, while granivores feed upon seeds. Plant fluid-feeding insects specialize on extracting the fluid components of either or both xylem and phloem; the fluid conducting vessels of the plant. This latter category of insects is also important as they may transmit many pathogenic microorganisms that cause viral, fungal, and bacterial diseases reducing plant health and, in some cases, causing plant mortality.

Within each of these categories of insect herbivory there is a tremendous level of variation in the degree of host plant specialization. Many insect herbivores may feed on a specific tissue associated with only a few species of plants. Others may feed on many species of plants. Through herbivory, insects are important in the overall regulation of plant communities by thinning overly dense plant populations and removing stressed and diseased individuals. Under poor forest management, where plant densities are allowed to become extreme, or when extensive drought conditions persist for years reducing plant defensive capabilities, populations of insect herbivores can rapidly increase in density leading to massive forest die offs (Fig. 1.8).

The importance of insects in food webs goes much further than just herbivory. Insects, not just herbivores, are a vital source of food (energy and nutrients) to a tremendous variety of vertebrates including fish, amphibians, reptiles, birds, and mammals (Capinera 2011).

In addition to partially regulating plant communities through herbivory, insects also provide a variety of beneficial services. One of the more important of these services is biological control. When presented with optimum growing conditions coupled with limited or absent predation and parasitism, herbivorous insect populations can explode in density and geographical expanse while significantly reducing the capacity of forest ecosystems to provide services and/or triggering large-scale ecosystem changes. This is especially the case with successful insect invasions in which existing natural predators and parasites are absent (Brockerhoff and Liebhold 2017). Importation and release of specifically adapted insect predators and parasites from the areas of origin of the invasive species may restore the ecological balance such that the densities of the invasive species are held below damaging levels. In normal functioning forests without invasive species, insect predators and parasites play key roles in naturally managing herbivorous insects below damaging densities (Kidd and Jervis 1997, but see Rosenheim 1998) (Fig. 1.9).

Fig. 1.8 Mountain pine beetle infestation. © Dezene Huber, University of Northern British Columbia, used by permission

Granivorous insects, through the process of harvesting seed on which to feed, often inadvertently disperse viable, undamaged seed. Although some seed will be consumed, some will be dispersed to new unoccupied habitats; thus providing a benefit to the plant.

Although wind-pollination is critical for coniferous forests and grasslands, non-grass flowering Angiosperms rely on mutualistic pollination by animals, the majority of which are insects. Indeed, the success of flowering plants is partially the result of tens of millions of years of coevolution between insects and plants. Most pollinating insects can be found within the Orders Hymenoptera (ants, bees, stinging wasps), Diptera (flies), Lepidoptera (moths and butterflies), and Coleoptera (beetles) (Fig. 1.10); although, any insect feeding on flowers, pollen, or nectar, has the potential to provide pollination services.

Many insect-plant pollination associations are mutualistic in nature by which plants require and benefit from insect-transfer of pollen, and insects receive flower nectar and/or pollen as a food resource. Additionally, insect predators that forage on insect pollinators while pollinating may inadvertently assist in the movement of pollen between flowers or individual plants.

In addition to affecting plants by their feeding activities, insects (largely herbivores) also play an extremely important role as vectors of a wide variety of plant diseases caused by viruses, bacteria, fungi, and nematodes. Such diseases may be

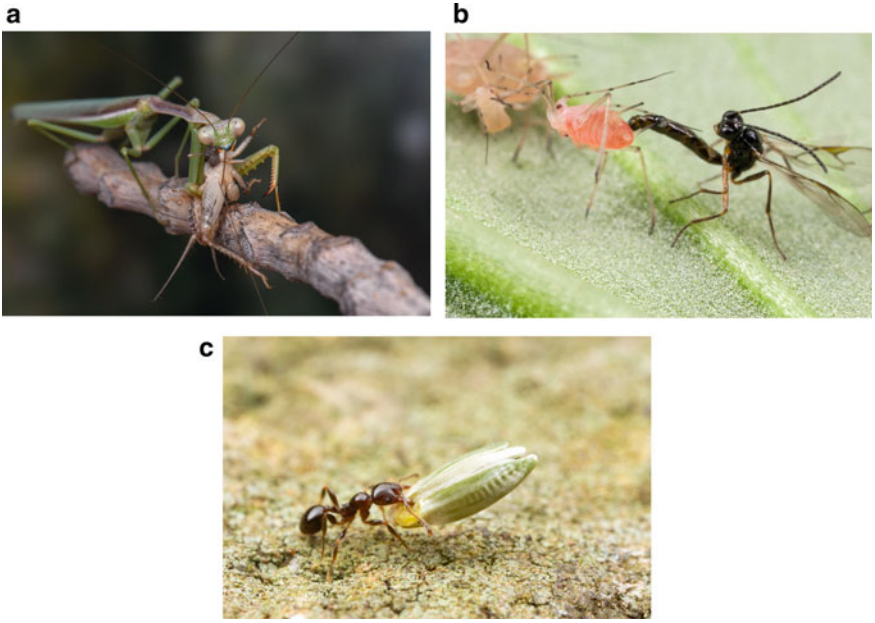

Fig. 1.9 **a** Mantid (a predatory insect with raptorial front legs) capturing and feeding on a cricket. © Ian Wright, used by permission. **b** *Aphidius ervi* (Hymenoptera: Braconidae) (a parasitic wasp) attacking an aphid. The wasp deposits and egg into the body of the aphid, and the developing wasp larvae feeds upon and ultimately kills the aphid. ©Alex Wild, used by permission. **c** Harvester ant collecting seed. © Alex Wild, used by permission

fatal and wide-spread resulting in complete loss of tree species (e.g. the Dutch Elm disease fungi transmitted by bark beetles). Others may only result in poor tree growth and branch die back (e.g. *Xylella* bacterial diseases in many species of Eastern North American hardwood forests). Many plant viruses that affect trees and understory plant species are transmitted by a host of aphids. Several species of bark beetles not only directly damage their hosts through feeding, but rely on mutualistic associations with fungal species to overcome host tree defenses. Cerambycid beetles are the primary insect vector of pine wood nematode which causes pine wilt disease. It should also not be overlooked that a number of insect species (e.g. mosquitoes and other biting flies) found in forests may transmit diseases that affect humans, domestic livestock, and wildlife (various species of *Plasmodium* [(i.e. malaria], West Nile and other arboviruses, plague).

1.3.3 Insect Decline

There has been growing concern and evidence for global declines in insect biodiversity (Wagner 2020). Loss of insect biodiversity has been detected on every continent

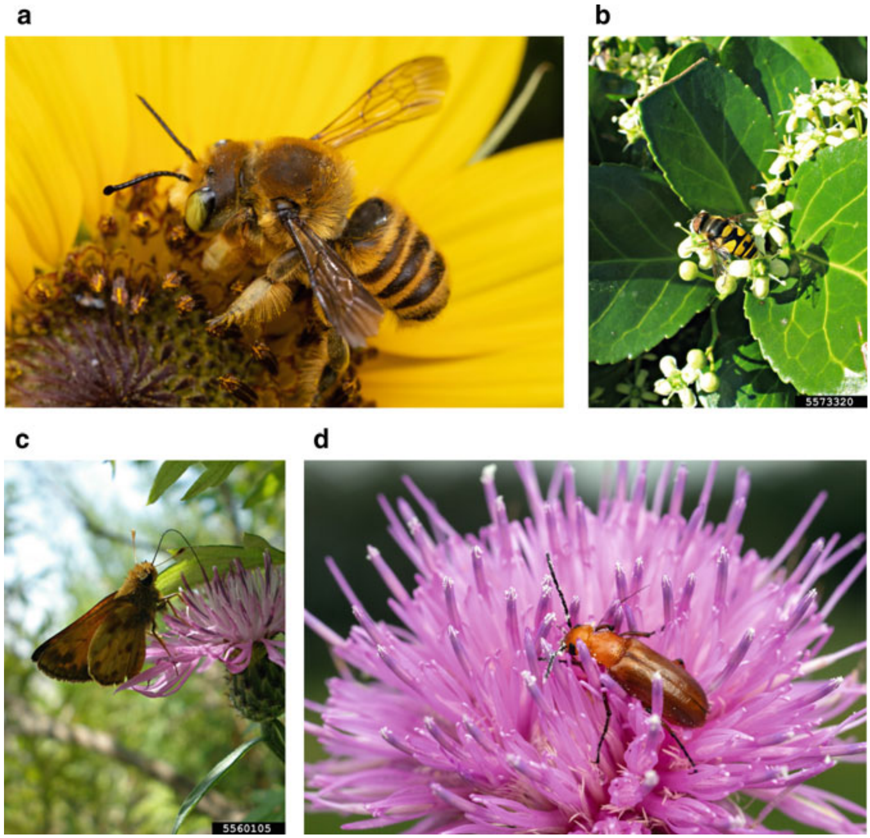

Fig. 1.10 Representative pollinators. **a** A native leafcutter bee (Hymenoptera). © Alex Wild, used by permission. **b** A syrphid fly (Diptera). © Ansel Oommen, Bugwood.org. **c** A skipper butterfly (Lepidoptera). © Ansel Oommen, Bugwood.org. **d** A flower-feeding blister beetle (Coleoptera). © Alex Wild, used by permission

where it has been examined. These losses have been documented for multiple types of terrestrial and aquatic insect communities. Potential causes of these declines are many and it is likely that no one factor is responsible for declines everywhere. The causes are not unique to the loss of insect species and are generally attributable to human activities: habitat loss and fragmentation due to agriculture, urbanization, recreation, pollution; climate change; and increase in transport and establishment of invasive species. The implications of these findings are serious as the degradation or loss of many of the ecosystem services that insects provide, including linking the earth's food webs (which include humans), would be catastrophic. Hopefully, with additional research and monitoring, both global and local factors responsible for these declines can be clearly identified and mitigated.

1.4 Summary

Insects are found in almost all ecological niches within the forests of the world and forest animal life, similar to other terrestrial ecosystems, is dominated by insects. Collectively, insects perform critical ecosystem services that maintain the health of the planet. The overwhelming majority of forest insect species are beneficial or are neutral in their impact on humans. Indeed without insects, most terrestrial ecosystems would likely collapse. Nonetheless, there are a relative very few, but very important, forest insect pests that either directly damage trees and understory plants or transmit damaging plant pathogens via their feeding behaviors (e.g. spruce budworms, various defoliators and sucking insects, several species of bark beetles and other wood boring insects, and newly arrived invasive species). It is not unusual to see outbreak populations of these pest species in overgrown, unnaturally dense, poorly managed forests and/or in forests subjected to long periods of drought. Often, these few pestiferous species must be managed in order to protect natural resources, and the management often involves the application of insecticides which have their own set of broad spectrum deleterious impacts. Failure to successfully manage pest species often leads to additional forest decline and further threatens overall species diversity ecosystem health. In 1987, the famed biologist E. O. Wilson published a paper entitled "The Little things that run the world" in which he emphasized the global importance of insects to the health of the planet (Wilson 1987). That statement is even more true today than it was 35 years ago.

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