Chapter 3

Climate Change and Arthropods: Pollinators, Herbivores, and Others

Sandra L. Brantley[1] and Paulette L. Ford[2]

[1] Museum of Southwestern Biology, University of New Mexico, Albuquerque, New Mexico

[2] U.S. Forest Service, Rocky Mountain Research Station; Grassland, Shrubland, and Desert Ecosystems Program; Forestry Sciences Laboratory, Albuquerque, New Mexico

Executive Summary

The Interior West is rich in arthropod diversity because of its varied topography, which provides a wide range of elevations and levels of isolation for these small animals (Parmenter and others 1995). Some taxa are known rather well, such as butterflies and tiger beetles, but we have little information on many groups, which are known only from a few locations although they are probably more widespread. Arthropods live at large to small scales (e.g., migrating butterflies crossing countries to habitat specialists on rock outcrops or sand dunes). They may be generalists or specialists, vagile or sedentary, and have immature life stages that are similar or different from the adult (Triplehorn and Johnson 2005).

Predicted climate changes for the interior of North America, particularly the western portion, include:

- drier summers,
- increased precipitation outside the summer season, and
- increased frequency of extreme events such as heat waves.

Arthropods are ectothermic, so the temperature increases associated with global warming directly affect their development time, usually by decreasing the time needed for immature stages to become adults. This allows not only more generations per year in a given habitat, but it also opens new habitat for colonization because minimum temperatures no longer exclude arthropods (Crozier 2003; Robinet and Roques 2010).

The ecological roles of arthropods are important, even critical, and should be included when monitoring and predicting effects of global warming. Although knowledge of many arthropod species is lacking (Cane and Tepedino 2001), some groups have been studied in many areas and for long periods, such as butterflies, grasshoppers, some bees, and some ants. While these groups do not represent all arthropods, data about them give us a place to start in understanding their responses to climate change.

Research needs for arthropods include:

- There is a lack of data for many species and scientists are urged to develop long-term monitoring efforts with as many taxa as possible. There is also a great need to identify species interactions as climate changes, whether between insects and host plants or among insects and their competitors and predators.
- Several studies have shown the value of museum collections and data from natural history surveys. There is increasing need and emphasis from funding sources on

grantees to publish specimen holdings online, including images, in order to build a more comprehensive understanding of species distributions.

- In the western United States, there is much state and Federal land that could be used for surveys and other interdisciplinary efforts. Opportunities are needed for collaborations among state and Federal agencies, universities, long-term ecological sites, state natural history surveys, and other natural heritage programs.

Introduction

The large number of arthropod (insects and their relatives) species in the world often means they are underrepresented in diversity assessments because of their "challenging taxonomy," meaning that they can be hard to identify and many species have yet to be described. The Interior West is rich in arthropod diversity because of its varied topography, which provides a wide range of elevations and levels of isolation for these small animals (Parmenter and others 1995). Some taxa are known rather well, such as butterflies and tiger beetles, but we have little information on many groups, which are known only from a few locations although they are probably more widespread.

The ecological roles of arthropods are important, even critical, and should be included when monitoring and predicting effects of global warming. Important ecological "services" provided by insects include:

- Pollination
- Herbivory
- Seed dispersal
- Soil aeration and mixing
- Plant/animal decomposition
- Predation/parasitism
- Food source for many vertebrate species

They live at large to small scales (e.g., migrating butterflies crossing countries to habitat specialists on rock outcrops or sand dunes). They may be generalists or specialists, vagile or sedentary, and have immature life stages that are similar or different from the adult (Triplehorn and Johnson 2005).

Arthropods are ectothermic, so the temperature increases associated with global warming directly affect their development time, usually by decreasing the time needed for immature stages to become adults. This allows not only more generations per year in a given habitat, but it opens new habitat for colonization because minimum temperatures no longer exclude arthropods (Crozier 2003; Robinet and Roques 2010).

Many of these species depend on plants as food for immature and adult stages; an expected problem is the different effects of climate change on plants and insects, resulting in mismatches in timing between insects and their host plants (e.g., budburst, flowering time, and seed production). Species living at high elevations may continue moving up until there is no place left to go, and specialists may lose habitat or other resources to climate change and other effects such as land use change.

Some of the current shifts in distributions give the impression that arthropods can accommodate temperature increases, but they cannot continue shifting indefinitely, especially if projected temperature increases become larger. In addition, it is important to remember that not all species will respond the same way to changes in temperature, precipitation, and/or shifts in vegetation. We present research from western North America when possible and expand to Europe, the Northern Hemisphere, or the globe when no more specific information is available.

Key Issues

Predicted climate changes for the interior of North America, particularly the western portion include:

- Drier summers
- Increased precipitation outside the summer season
- Increased frequency of extreme events, such as heat waves (Easterling and others 2000; Seager and others 2007; Diffenbaugh and Ashfaq 2010)

Over the Twentieth Century, average temperatures have increased about 0.6 °C, not only as higher maximum temperatures but also as higher minimum temperatures (Easterling and others 2000; Parmesan 2006) (i.e., there may be less difference between daily highs and lows). Seager and others (2007) suggested that one cause for these changes is a shift in atmospheric circulation cells toward the poles that is allowing sub-tropical dry zones to expand northward. Even if greenhouse gas levels do not increase above current levels, overall temperature increases will probably be 2 to 4 °C (Diffenbaugh and Ashfaq 2010).

Throughout the Midwest and the Southwest, the number of extreme precipitation events has increased over the Twentieth Century (Easterling and others 2000). Diffenbaugh and Ashfaq (2010) reported model results looking toward 2039, predicting increased winter precipitation but drying during the summer, so that soil moisture will decrease and evapotranspiration will increase. The authors also found that the Southwest is likely to experience summer heat waves every second or third year. Drought events from the El Nino Southern Oscillation system will also continue to occur and make the region drier still during those years (Seager and others 2007).

Within these broad-scale predictions, local conditions will vary, especially in arid regions where large daily temperature changes and variable precipitation virtually define the area (Noy-Meir 1973). Western North America contains numerous mountain ranges, which collect precipitation and nutrients such as nitrogen (N) and phosphorus (P) from air pollution. The complex topography can either retain these resources or transport them far from the source through watersheds (Seastedt and others 2004).

Increased winter precipitation in southeastern Arizona over 20+ years (Brown and others 1997) has resulted in species change in vegetation, insects and small mammal communities. Shrub establishment was improved so that they became a larger proportion of the vegetation cover, while grass species declined. Such a pattern had also been attributed to grazing effects or drought, but those factors were not involved at Brown and others' (1997) site. The number of arthropod species present at the site did not change significantly but species composition did. The seed harvester ants *Pogonomyrmex rugosus* and *P. desertorum*, originally dominant species, became locally extinct, while *Pheidole xerophila*, also seed collectors, did not change, showing the independent response of species, even within one subfamily (Myrmicinae).

Chapin and others (2001) examined possible impacts on biodiversity across world biomes from five drivers: climate change, land use change, N deposition, biotic exchange (e.g., invasive species), and increased atmospheric CO_2. The authors found that land use change produced impacts as large as or larger than climate change for most biomes (results summarized in Sala and others 2000). In many areas, land use change has already altered biodiversity extensively, so that climate change has not produced much additional change. As an example for deserts, Huenneke (2001) described the Chihuahuan Desert of southern New Mexico as an area further desertified by agricultural and grazing use. For grasslands, Sala (2001) noted that conversion to agriculture is the major impact and that climate change effects are expected to be moderate. Other human-caused factors of importance to grasslands are pollution from nearby cities and loss of water to cities and agriculture.

In desert systems, increased precipitation is usually thought of as beneficial, but if it arrives at the wrong time of year and as extreme events, as is predicted by Easterling and others (2000), the effects can be harmful, washing away soils, and ruining seed banks and insect eggs, and affecting water quality in rivers and lakes. In particular, specialist arthropods will be impacted because their host plants or substrates tend to be patchy in distribution in arid systems (Huenneke 2001).

Arthropods vary widely in their abilities to avoid or tolerate these kinds of changes. The distributions of many of the thousands of species are poorly understood, making it difficult to know how or if they will be affected by land use and changing climate. Because insects are ectothermic, temperature increases that most commonly characterize climate change will undoubtedly affect them in various ways such as more rapid development through life stages, more generations per year, and an increase in favorable habitat that was formerly too cold.

There may also be contraction of species' ranges as some areas become too hot (Robinet and Roques 2010). If species are forced to move out of habitats that have become too hot, they are seen as "rescued" by having moved northward or up in elevation (Parmesan 2006). However, a given species may not be able to maintain populations in these new areas because of substrate or food needs and because there will already be other species established there. It is not clear that the shifting populations are undergoing genetic change over the short term to better fit them to the new habitats (Parmesan 2006). A likely negative impact will be a mismatch or asynchrony with host plants for larval growth or maintenance of adults during their reproduction periods (Parmesan 2007; Robinet and Roques 2010).

Following, we discuss current knowledge of representatives of pollinators, herbivores, omnivores, and detritivores (scavengers).

Pollinators: Butterflies

By far, the best known pollinators are butterflies because of their rather large size, relative ease of field identification, and attractiveness to the general public. They have become the representatives of all insects in climate change studies because datasets are available for them (Inouye 2007). However, butterflies do not necessarily respond as other insect taxa do (Hickling and others 2006), highlighting a need for monitoring studies of other groups.

In the western United States, many studies have been done for the Pacific Coast (e.g., McLaughlin and others 2002; Crozier 2003; Preston and others 2008), but fewer have focused on the interior of the continent. In two mountain ranges in Nevada, Fleishman and MacNally (2003) studied species richness of butterflies from 1996 to 2002, testing how well a series of short sampling periods or "snapshots" would detect possible climate change effects. Their results showed that richness between the mountain ranges and even among sites within a range were greater than any changes across the six years. Species living successfully in arid climates already had life history strategies for habitat variability in abiotic and biotic resources (what the authors called "tough-tested"). In an earlier study modeling species changes in six mountain ranges (one in California, five in Nevada), Fleishman and others (2001) used a climate scenario that increased temperatures enough to move plant species up in elevation by 500 m. The butterflies were expected to move as much also, assuming their dispersal capabilities were good. Under a moderate temperature increase, the Great Basin area would probably not lose many butterfly species, but each mountain range had its own patterns of species richness making it impossible to generalize outcomes to other areas.

Climate change patterns not only show an increase in maximum temperatures but in minimum temperatures as well, so that some areas experience fewer days of freezing or very cold weather. These minimum temperatures are increasing at a faster rate than the maximum temperatures (Easterling and others 2000; Parmesan 2006) and are important to monitor for their effects on arthropod distributions. Crozier (2003) tracked the northward movement of the sachem skipper (*Atalopedes campestris*) from its historical range in the southern and western United States and Mexico as it moved up the Pacific Coast to Eugene, Oregon, in 1967; Portland, Oregon, in 1985; Tri-Cities (Richland, Kennewick, and Pasco) area of Washington in 1993; and Yakima, Washington, in 1999. Her work showed that the skipper is limited by low temperature and can readily take advantage of increasing temperatures to move into new areas. The host plants for this species are grasses (Brock and Kaufman 2003), including crabgrass and Bermuda grass that are planted in cities and towns, so not only climate change but also conversion of land to urban settings favor the spread of this species. The author encouraged conservationists to not only save current habitat but also areas that may become suitable in the future.

A European butterfly dataset from the past 30 to 100 years found similar shifts (Parmesan and others 1999). For species whose entire range was known, the authors found 22 extended distributions to the north, 2 extended distributions to the south, and 11 remained stable. These changes reflect the 0.8 °C increase in temperature over the last century, suggesting that a further increase of 2 to 4 °C could leave some species with no further possible movement northward or upward in elevation. Poor dispersers would be particularly at risk because of the added factor of increasing habitat fragmentation, leaving them in shrinking "islands" of climatically suitable habitat.

Forister and others (2010) investigated the combined effects of climate change and habitat loss, the two most important drivers of species change (Sala and others 2000), on butterflies in the Sierra Nevada in California. The data covered 159 species over 35 years and an elevation gradient of 0 to 2775 m. The elevational gradient allowed the authors to determine whether climate or land use produced species changes. At lower elevations where human populations were higher, the greater impact on butterflies came from habitat loss. At intermediate and high elevations, climate change was the likely cause of species change. At middle elevations, species moved up, and at the highest elevations (alpine), habitat specialists declined as conditions warmed, but overall species and abundance increased because of the influx of intermediate elevation species. An unexpected result was the decline in ruderal species at low elevations. These widespread species are generally predicted to do well in the face of climate change. In this case, however, habitat destruction was severe enough to remove both larval host plants and nectar sources for adults, showing that even generalist species may also need conservation protection in some areas. The authors suggested that one reason generalists do well in Europe is that they have had centuries to adapt to land use change; what we see there today are the species that are successful in highly disturbed and managed habitats.

Generalist butterfly species were predicted to do well in Canada, based on models by White and Kerr (2007), for 102 species. The authors built a long-term dataset from museum records (some extending back to the Nineteenth Century) and added geographic features such as elevation and changes in land use, temperature, and precipitation. Temperature and elevation were the best predictors of butterfly species richness; precipitation was an important factor only in the driest areas, the prairies of south-central Canada. As is common in other studies, the authors found a decline in specialists due more to loss of forest habitat than climate change. High richness was found in two areas but for different reasons: in high elevations, habitat heterogeneity provided many suitable microhabitats; but in lower elevations, which are dominated by people, diversity was high because of land use change. The increased expansion of already widespread generalist species has led to what the authors called a "homogenization" of species across the southern part of the country. Though the diversity is high, it is being maintained by disturbance and agriculture.

From a pair of studies, we can compare two closely related butterflies, the Quino checkerspot (*Euphydryas editha quino*) and the Bay checkerspot (*Euphydryas editha bayensis*) in California. The Quino checkerspot is a well-studied endangered subspecies that is a habitat specialist in the shrublands of southern California. Preston and others (2008) modeled its possible population changes under temperature and precipitation changes. With a temperature increase of 0.6 °C and no change in precipitation, the butterfly would probably do well. Under temperature increases of 1.7 and 2.8 °C and precipitation changes of -50% or +150%, suitable habitat would be reduced by 98 to 100%. In this Mediterranean-type habitat, drought can be common, so the modeled reduction in precipitation would understandably produce habitat loss, but it is interesting to note that precipitation increases also virtually wiped out the habitat. In both cases, vegetation species and cover would presumably change so much that the butterfly could no longer be supported. Larval host plants are dwarf plantain, penstemon, and Indian paintbrush (Brock and Kaufman 2003). As a specialist, it is unlikely to move readily to grasslands or forests even if they are relatively close.

The Bay checkerspot butterfly (*Euphydryas editha bayensis*) is also a specialist on the same plants as the Quino checkerspot (Brock and Kaufman 2003) but lives in grasslands of the San Francisco Bay area of California. McLaughlin and others (2002) investigated the factors leading to the extinction of two populations (in 1991 and 1998) of this threatened subspecies. The most important factor was a change in the pattern of precipitation: increased variability after 1971, including more severe weather events. The larvae and their host plants were also affected, with a shortened period of overlap and a resulting increase in larval mortality. A second impact on the populations was the loss of metapopulations nearby to recolonize the area because of habitat fragmentation and urban growth.

Pollinators: Bees

Although bees are major pollinators of many wild and managed plants, they are less well-known than butterflies (Inouye 2007); many species are difficult to identify in the field. In North America, there are few data to document a decline in these pollinators because of high interannual variation in abundance, the effort and expense needed to adequately monitor and identify bee diversity, and our lack of knowledge about suitable habitat for many species (Cane and Tepedino 2001). Studies show varying amounts of response to climate or disturbance impacts; each local area has its own combination of factors that influence richness and abundance.

In 1997, the U.S. National Research Council published a report on the status of pollinators in North America in agricultural settings. Along with the honeybee (*Apis mellifera*), common introduced species that are extensively managed for crop production include several bumblebee species (*Bombus* spp.) and a leafcutter bee (*Megachile rotundata*). All are susceptible to parasites, pathogens, and pesticides, as are native species. In addition, these introduced generalist species frequently outcompete native species by reducing overall nectar availability in some areas. At present, the authors concluded that the effects of transgenic corn with incorporated *Bacillus thuringiensis* (Bt) poses a small threat to native bee species because Bt targets herbivorous caterpillars. However, a greater cause for concern is that crops with increased herbicide resistance allow farmers to treat their fields for weeds without damaging their crop species. Those weeds are nectar sources for many native bee species. If more cropland is developed with these resistant plants, a possible indirect result will be the loss of native pollinators on non-crop plants.

Little information about bees is available for western North America (Cane and Tepedino 2001), but two studies in the Rocky Mountains of Colorado illustrate shifts in the relationships between bumblebees and their host plants. Inouye (2007) has been monitoring bumblebees for several decades in the area surrounding Rocky Mountain Biological Laboratory in Crested Butte. At least one bumblebee species has moved upward some 457 m in elevation with a corresponding 1.4 °C increase in temperature during this time. Further temperature increases of 2 to 4 °C are predicted for the western United States over the next 30 years (Diffenbaugh and Ashfaq 2010), and it is not clear if bumblebees will be able to keep up with such change. Inouye (2007) noted that host plants may not be moving at the same rate as their pollinators (also in Parmesan 2007) because their needs also include soil moisture and substrate type.

In the second study in western Colorado, Thomson (2010) studied blooming and fruit set of a lily, *Erythronium grandiflorum*, which is pollinated by bumblebees. Some members of the lily population start blooming early as soon as snow melts, which may vary by a month from one year to the next. There were occasional frosts even after snowmelt, and even when early and mid-period blooming individuals survived frosts, they were often limited by the small number of pollinators available (they are ectothermic and limited by very cold temperatures). Later-blooming individuals had the advantage of a greater number of bumblebee colonies. Thomson reported that the lack of synchrony between lily and bumblebees has worsened in recent years. If winter precipitation patterns and extreme storm events increase as predicted (Easterling and others 2000), early blooming lilies will be severely limited by frosts and the lack of bumblebees.

In Carlinville, Illinois, Marlin and LaBerge (2001) compared bee data from surveys in the 1970s with records from Charles Robertson's surveys from 1884 to 1916. Of the 214 species that Robertson collected, Marlin and LaBerge found 140 (65%) in their surveys, as well as 14 species that Robertson did not collect. Since the 1880s, the area has lost and gained forest cover and has increased the amount of land converted from prairie to agriculture, yet the bee fauna was largely intact. The authors attributed this to a diversity of remnant habitats between agricultural fields. Winfree and others (2009) for bees, and Forister and others (2010) for butterflies, showed that insects managed relatively well below a threshold of extreme disturbance; the Illinois bee fauna in the 1970s had perhaps not experienced such severe disturbance. These studies show that in some cases, pollinators can cope with low to moderate levels of disturbance.

A more recent European study documented broader patterns and explanations for declines in bees. Biesmeijer and others (2006) took advantage of a good historical record of bee distributions in Britain and the Netherlands to compare changes in species richness in 10 km x 10 km map grid cells before and after 1980. For grid cells with enough data, bees in Britain declined in 52% of cells and increased in 10%, while in the Netherlands, bees declined in 67% of cells and increased in only 4%. The species with the largest declines were specialists on certain flowers or habitats, had only one generation per year, and did not migrate. The authors also found that plant species with specialist pollinators declined, wind-pollinated species increased, and self-pollinating species showed no change. In Britain, species increases were for those that were already widespread (as in White and Kerr [2007] for Canadian butterflies). In both countries, species became less evenly distributed, that is, fewer species made up a larger proportion of those present.

Winfree and others (2009) used datasets from the world in a meta-analysis of bees and human disturbance. Although their questions did not include climate change, their work showed the importance of land use change in altering bee communities. The biological aspects they looked at were managed versus wild species and solitary versus social species, grouping genera into *Apis*, *Bombus,* and other. Disturbance factors included habitat loss/fragmentation, pesticide use, fire, deforestation, and grazing. Habitat loss was the primary factor reducing bee species and abundance, but only when such loss was extreme. This was also the case with Sierra Nevada butterflies (Forister and others 2010) and their results agree with the predictions of Sala and others (2000). By dividing the bee data by genus and life history features, it became clear that disturbance impacts were varied (e.g., tree-nesting species would be negatively affected by deforestation, but the increase in open land might favor ground-nesting species). However, even with the combined power of multiple studies, it is not possible to extrapolate these results to all bees in all areas.

Pollinators: Flies

The true flies, Order Diptera, are a hyperdiverse group with over 21,000 species (86% endemic) in the Nearctic (Bio Systematic Database of World Diptera). They are usually thought of as disease vectors (mosquitoes), crop pests (leafminers), or livestock pests (stable flies), but they are important parasitoids of other arthropods and are pollinators as well. As pollinators, many species are generalists, but the syndrome called sapromyophily (flowers producing appearances or scents of decaying flesh as attractants) shows that plant-fly interactions have existed for long periods to produce such specializations (Kearns 2001). Flies are common at high elevations, pollinating a variety of arctic and alpine plants (Kearns 2001). Although they are often not the target of studies of plant-insect interactions in these habitats, large numbers of individuals may be collected but not prepared or identified because of time/budget constraints. Their identification can be difficult, but depositing specimens in museums can provide material for future research. Syrphidae, also known as flower flies or hoverflies, is a family of common and important pollinators (Triplehorn and Johnson 2005). In Britain and the Netherlands, Biesmeijer and others (2006) studied syrphid fly records before and after 1980 in 10 km x 10 km map grid cells as previously discussed for bees. In Britain, syrphid richness increased in 25% of cells but decreased in 33%, while in the Netherlands, richness increased in 34% of cells and decreased in 17%. The authors interpreted these changes as shifts in species' distributions in many cases. The study showed larger declines of specialists and those with only one generation per year. Compared with bees in the same study, the syrphid flies did not decline as much, perhaps in part because their larvae are more varied in food sources (some are predators, others are detritivores, and others are herbivores, while bee larvae feed only on pollen and nectar) (Triplehorn and Johnson 2005).

Herbivores

Two important groups of insects that feed on foliage are grasshoppers (Orthoptera) and moths and butterflies (Lepidoptera). Grasshoppers feed on foliage in all life stages, while lepidopterans feed on foliage in the larval or caterpillar stage. As adults, moths and butterflies are often important pollinators; (butterflies are discussed in the "Pollinators" section). There is little information on responses of moth pollinators to climate change. In Missouri, Forkner and others (2008) studied 15 families of moths whose caterpillars feed on oak leaves. Among these species were those with one generation per year or several, seasonal feeders or those feeding most of the year, and those that were mobile or that fed in leaf rolls or mines. The study questions involved variability in population density as a way of predicting which life history patterns might be more vulnerable to climate change. Those with the highest variability were spring feeders that were not mobile, suggesting that they may be most vulnerable to a mismatch in timing between caterpillar development and oak budburst. Species that fed over a longer period and that could move within or between trees would be able to compensate for plant/insect timing mismatches.

Melanoplus sanguinipes, the lesser migratory grasshopper, is found over all of the United States (except for Florida and western California) and into southern Canada (Capinera and Sechrist 1982), and because it can be an outbreak species on agricultural crops, it has been monitored well in some areas. Olfert and Weiss (2006) used records from Saskatchewan from 1931 to the present to model its possible response to climate warming. The most favorable habitats for the grasshopper were mixed grassland and moist mixed grassland. Under conditions of a 2 °C temperature increase, the species became a possible outbreak pest in 17.3% of Canada. With a 4 °C increase, the species colonized new habitats such as the Boreal Plains and Boreal Shield, and Canada's susceptibility to outbreaks increased to 28.2%. With a 6 °C increase, the species would be able to live in most of Canada. In all scenarios, *M. sanguinipes* had the potential to become a major pest in cereal crops.

Nufio and others (2009) made use of a collection of grasshopper data at the Colorado Museum of Natural History by comparing Gordon Alexander's collections from 1958 to 1960 with the present. Alexander surveyed grasshoppers at different elevations in the Rocky Mountains near Boulder, Colorado. Preliminary results from the present-day comparison showed that species are hatching and reaching adulthood 15 to 30 days earlier than in Alexander's time. Work will continue through 2012 (see www.ghopclimate.colorado.edu).

Omnivores: Ants

On a global scale, ants are thermophiles, with highest diversity in the tropics. In North and South America, their richness, both past and present, is well explained by temperature (Dunn and others 2009), but under current climate conditions, fewer species were found than expected in North America. Dunn and others (2009) suggested that current richness represents a loss due to past climate change as far back as the Eocene, after which North America began to cool more than South America. Some North American fossil species represent taxa that are now found only to the south in more tropical habitats. It is likely that increased temperatures will allow not only current species to move north but also allow species that were formerly in North America to return.

In western North America, Kaspari and others (2000) studied ants in numerous habitats: desert shrubland, grassland, coniferous forest, and tundra. They accounted for 70% of ant abundance through positive correlations with temperature, plant productivity, and seasonality. From this, the expectation was that increased regional temperatures would favor the activity and spread of ant species, but the authors suggested that the ants have also benefited from cold winter temperatures through lower metabolic costs. A shorter winter season would increase the amount of time available for foraging but there might not be increased plant productivity, in which case the ants would not recover their energy investment through seed harvesting or predation on herbivorous insects.

Detritivores and Predators

Very little work has been published on the effects of climate change on arthropods that have little impact on human activities. However, in Britain, Hickling and others (2006) compared occurrence records from 1960 to 1975 with those from 1985 to 2000 for many taxa. Species that were included were those found only in southern or lower elevations in Britain in the earlier years to see if they moved northward in the later years. On average, species shifted northward 31 to 60 km or upward 25 km. These shifts were significant for grasshoppers, butterflies, long-horned beetles, ground beetles, soldier beetles, metallic wood-boring beetles, millipedes, isopods, spiders, and dragonflies. Shifts were not significant for lacewings or harvestmen. These taxa cover a range of ecological roles, including predators, detritivores, and herbivores, with implications for local changes in ecosystem processes. Species responded independently; there was no overall pattern within a taxon or trophic group. The species considered here were moving at sometimes different rates than better-monitored species, such as butterflies. We should not assume that information on only a few taxa will be a good substitute for all arthropods.

Synthesis

A number of general patterns emerge from the information presented:

- Land use change (habitat loss/fragmentation) is as important as climate change as a driver for altering insect populations and communities. In some areas, species richness has already been affected by habitat loss, so climate change may not produce much more of an impact.
- Many insects have already expanded northward or upward in elevation in response to the 0.6 °C temperature increase of the last century. An additional increase of 2 to 4 °C as predicted may mean a permanent loss of habitat for some species.
- Many insect species are resilient to low to moderate amounts of disturbance. These changes favor some species and disfavor others.
- The mismatch between insects and their host plants is increasing for some species. Species most at risk are host specialists, active early in the growing season, poor dispersers, and/or have only one generation per year. Generalist species are likely to become even more widespread. There is a lack of information on interactions as a result of species shifting into new areas.
- There are not enough long-term datasets on most insect species. The predictions from models need to be validated with more field data—model results can vary widely. Insect species respond independently to environmental changes, so studying only a few species will not predict what the rest will do. Monitoring must involve interdisciplinary efforts to integrate data on species, climate, and other environmental factors.

Research Needs

- Almost all of the researchers cited in this chapter have noted the lack of data for many species and urged current workers to develop long-term monitoring efforts with as many taxa as possible. There is also a great need to look at species interactions as climate changes, whether between insects and host plants or insects and their competitors and predators.
- Several studies have shown the value of museum collections and data from natural history surveys. There is increasing emphasis from funding sources on grantees to publish specimen holdings online, including images, to build a more comprehensive understanding of species distributions.
- In the western United States, there is much state and Federal land that could be used for surveys and other interdisciplinary efforts. We can create opportunities for collaborations among state and Federal agencies, universities, long-term ecological sites, state natural history surveys, and other natural heritage programs.

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