Chapter 15

Arthropods in Canada’s Grasslands: Synthesis and Future Directions

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The vast ocean of level prairie which lies to the west of Red River must be seen in its extraordinary aspects, before it can be rightly valued and understood in reference to its future occupation by an energetic and civilised race, able to improve its vast capabilities and appreciate its marvellous beauties. It must be seen at sunrise, when the boundless plain suddenly flashes with rose-coloured light, as the first rays of the sun sparkle in the dew on the long rich grass, gently stirred by the unfailing morning breeze. . . . the mind forms a true conception of the Red River prairies in that unrelieved immensity which belongs to them in common with the ocean, but which, unlike the ever-changing and unstable sea, seem to promise a bountiful recompense to millions of our fellow-men.

—Henry Youle Hind, 1860

The quotation from the writings of Henry Youle Hind (1860), an early explorer of Western Canada, paints an attractive picture of the Canadian prairies in the mid-1800s. However, Hind’s words reflected a lack of understanding of the complexity and significance of the biota there and were a warning of changes that were about to occur in nearly all of Canada’s grasslands. His words also relate to the message that permeates this book, and indeed most modern writings on North American grasslands: Our grasslands are in a perilous state. Only about 9.4% of the original North American prairie remains as grassland (White et al. 2000) and there are likely few areas today among the grasslands of Canada where the biota approaches that of historical conditions. In southern Manitoba, all but a fraction of 1% of the tallgrass prairie has been converted to cropland, invaded by forest cover, or covered by urban sprawl. Only four publicly protected sites in Manitoba totalling less than 100 ha remain (Trottier 1992). It has been estimated that originally there were about 24 million ha of mixed grassland and moist mixed grasslands in southern Alberta, Saskatchewan, and Manitoba; however, only about 27% of this area remains unplowed, half of which is overgrazed (Trottier 1992, Gauthier and Wiken 2003).

Humans have made many changes to all grasslands in the southern regions of Canada and likely all of these changes have impacted the lives of arthropods. The majority of
grasslands have been cultivated and the remaining land has been altered by grazing or has been severely fragmented by roads, fences, pipelines, power lines, irrigation canals, and urbanization. Associated with the development of agriculture has been the loss of wetland habitat through drainage. Of an estimated 80,000 km² of wetland in the prairies before European settlement, about 70% has been destroyed for agricultural development (Canadian Wildlife Service 1991).

The introduction of chemical pesticides in the 1940s was another change that altered the arthropod diversity over large tracts of grasslands. Of all animals in the grasslands of Canada, insects have been the target of most chemical poisoning. As a result, the agroecosystems of modified grasslands are laced with tons of insecticides, with the most destructive pests evolving resistance (Pimentel et al. 1992). Insecticides become genetic selectors that benefit individuals with naturally occurring mutations in enzymes that detoxify the chemical, and these individuals reproduce to form resistant populations. Unfortunately, the casualties are the predators and parasitoids of the pest species, as well as harmless species that do not have the array of detoxifying enzymes that are commonly found in phytophagous pest species. Devine and Furlong (2007) provide a good overview of the harmful and beneficial impacts of insecticide use in various parts of the world and how this use is changing in response to increasing environmental awareness. However, the rapidly evolving resistance after the introduction of pesticides well illustrates the ability of insects to adapt to changing environmental conditions (Denholm et al. 2002).

Climate change is also a major factor that will influence the future abundance and distribution of biota in all ecosystems of the planet, including Canada’s grasslands (Dobson et al. 1989; Peters and Lovejoy 1992). Warmer temperatures are expected to increase levels of carbon dioxide and alter precipitation on grasslands, which are likely to suffer further habitat fragmentation and loss, making it difficult for all biota to adapt (Lovejoy and Hannah 2005; Pachauri and Reisinger 2007). There is growing evidence that insects are one of the first groups of living organisms to respond to global warming (Harrington and Stork 1995; Wilson et al. 2007). Hillstrom and Lindroth (2008) found that elevated CO₂ and O₃ altered the abundance of insects and composition of communities in forests, but did not affect family-level richness. Elevated CO₂ reduced the abundance of phloem feeders, increased the abundance of chewing insects, and increased numbers of parasitoids. In contrast, elevated O₃ had a negative effect on the abundance of parasitoids but increased numbers of certain insect herbivores. There seems little doubt that changes in CO₂ and O₃ will alter the composition of grassland arthropod communities, but much new research is required to determine what these changes will be.

Future Trends in Ecological Studies of Grassland Arthropods

Central themes in the science of arthropod ecology include the interaction of organisms with biotic and abiotic factors and how these interactions structure the composition and dynamics of communities (Price 1997; Schowalter 2006). Food chains comprising green plants, insect herbivores, and insect parasitoids contain over half of all known species of metazoans (Strong et al. 1984). As ecologist Robert May eloquently explained, “To a rough approximation, and setting aside vertebrate chauvinism, it can be said that essentially all organisms are insects” (May 1988). Not only are insects and mites abundant in most terrestrial habitats, but their total volume is also colossal, despite their small size. The biomass of all insects in temperate terrestrial ecosystems is estimated to exceed that of the total land vertebrate population by about 10 to 1 (Pimentel and Andow 1984). Arthropods
are the predominant metazoan herbivores, parasitoids, and predators and create the biological foundation for all terrestrial ecosystems (Scudder 2009). Arthropod detritivores are also abundant in grassland habitats and have a profound influence on ecosystem structure, processes, and function (Tscharntke and Greiler 1995; Whiles and Charlton 2006). Grasshoppers can consume 21–23% of available forage, and damage can exceed production by a factor of three (Tscharntke and Greiler 1995). Such disturbances vary considerably in time and space and are thought to play a central role in the organization of biotic communities (Carson and Root 2000; Gibson 2009).

Grassland insects and their arthropod relatives represent the full scope of heterotrophic strategies, from sessile species such as gallers and scale insects whose ecological strategies resemble those of plants, to social insects such as bumblebees and paper wasps whose range of behavioural attributes is comparable to that of advanced vertebrates. The geographical distribution of individual species generally reflects the environmental template established by latitude, global atmospheric patterns, temperature, and continental events such as glaciation. There is a rich literature on the ecology of insects (e.g., Price 1997; Speight et al. 1999; Schowalter 2006), and many of the disciplines of ecology (e.g., population dynamics, metapopulation ecology, regulation of ecosystem processes) have been enhanced by studies of grassland arthropods. Virtually any depiction of a food web in a grassland ecosystem will show arthropods as a key component.

All grassland plants are hosts to assemblages of phytophagous arthropods, which in turn are attacked by predators and parasitoids. Such assemblages form distinct communities, and understanding the factors responsible for their organization is a major preoccupation of ecologists. Grassland arthropod communities have much to offer ecologists because they are easier to reach, sample, and study than are communities in tall forest trees. It is relatively easy to census most of the key players in subunits of more complex, species-rich communities, known as component communities, and use them to consider the major hypotheses proposed to account for community organization (Price 1983) and the relative importance of each species. Information on arthropods at the community level is crucial if we are to learn about the relative importance of each species and find ways to sustain their populations.

One of the earliest objectives of ecologists was to explain the spatial patterns of arthropod distributions (Andrewartha and Birch 1954). Ecologists soon recognized that the geographical range of each species was determined by its tolerance to variation in abiotic conditions. Morphological, physiological, and behavioural adaptations of arthropods reflect the characteristic physical conditions of the habitats in which they occur. However, grasslands experience climatic fluctuation and both natural and anthropogenic disturbances that affect the survival of organisms in the community.

Although much research has addressed energy flow and nutrient cycling within grassland food webs (Price 1997), little is known about the importance of indirect interactions. For example, more needs to be learned about how herbivores feeding on leaves of grassland plants alter the resources for organisms feeding on roots (Masters et al. 1993) or how herbivores feeding early in the season affect the suitability of the host for those feeding on the same plant later in the season (Hunter 1987). Even grazers with voracious appetites, such as grasshoppers, can make positive contributions to ecosystem processes, such as nutrient cycling, and can serve as food for grassland birds (Branson et al. 2006). Grasshoppers and grasslands have had a long association and there is a close relationship between the health of grassland ecosystems and the biodiversity of grasshoppers (Guo et al. 2006).
One of the challenges for ecologists studying grassland arthropods has been to place the animals in an ecosystem context that represents their effects on ecosystem properties as well as the diversity of their adaptations and responses to environmental conditions (Schowalter 2006). Most arthropod ecologists have until recently concentrated on life history strategies and interactions with other species (Price 1997). This focus has yielded much information about individual species and the complexities of their associations. However, now an integrated interpretation of the responses of a diverse community to multiple environmental factors is needed: an ecosystem approach that integrates arthropod ecology with the changing patterns of ecosystem structure and function and that applies arthropod ecology to an understanding of ecosystem, landscape, and climate change and to sustainability of ecosystem resources (Schowalter 2006).

In the parts of Canada where grasslands have been converted to agroecosystems, many people in the business community have argued that environmental protection and conservation hurt the economy. In reality, just the opposite is true – a good environment is good for the economy, and, as Day et al. (2009) argue, an important role for ecologists in the coming decades will be to show the economic importance of the biodiversity that drives the ecosystem services that sustain humans. Although natural ecosystem services of the kinds provided by arthropods are absolutely necessary for human existence (Scudder 2009), the availability of abundant and cheap fossil fuels has distanced most people from direct contact with nature and obscured the important role of the natural world.

Day et al. (2009) suggest that the coming societal transition will affect the science of ecology and the roles of ecologists in understanding natural systems. These authors predict that as ecosystems such as rain-fed grasslands become relatively more important in supporting human economy as fossil fuels become scarcer, ecologists will be required to elucidate how we sustainably manage ecosystems without causing further deterioration and destruction. Ecologists will be expected to quantify connections between the biosphere and society and to help define the environmental and ecological realities and values that foster sustainability. More must be revealed about the relationship between loss of biodiversity and ecosystem degradation, and new ways must be found to reverse damaging trends of the past if we are to sustain human needs (Gibson 2009).

**Plant-Feeding Insects**

Phytophagous insects and mites comprise nearly half of all arthropod species on grasslands, as is the case in most terrestrial ecosystems. The most important taxa are Lepidoptera with phytophagous larvae, including beetles in the families Chrysomelidae (leaf beetles) and Curculionidae (weevils). In addition, Hemiptera (all the Sternorrhyncha and Auchenorrhyncha are feeders of plant fluids), Orthoptera (most species chew the leaves of plants), and Hymenoptera (e.g., Symphyta, gall wasps, and the pollen and nectar feeding bees) are phytophagous. Arthropods consume all anatomical parts of plants, with most species specializing on specific hosts and organs of these hosts (Schoonhoven et al. 2007).

Insect herbivores influence processes and functions of grassland ecosystems by altering plant populations and community dynamics. Through feeding and excretion, insects and other arthropods alter the quality and timing of litter inputs, contribute nutrients by their frass and honeydew, and alter energy budgets of damaged plants (Whiles and Charlton 2006). Herbivores can also influence litter quality and associated detrital cycles through premature abscission of plant parts, or “greenfall,” which are tissues removed during feeding but not ingested (Whiles and Charlton 2006).
Many species of sap-feeding herbivores are found on grassland flora. Those that feed on xylem remove mostly water and amino acids and can cause water stress and reduced productivity (Meyer and Whitlow 1992), whereas phloem feeders remove appreciable amounts of sugars and can act as carbohydrate sinks (Inbar et al. 1995). Gall-inducing insects are found on many grassland plants, including forbs, shrubs, and trees (see Chapters 12 and 13), and influence the transport of assimilates within attacked organs (Harris and Shorthouse 1996). Numerous arthropods feed on flowers and seeds of grassland plants. Those feeding on pollen and nectar can greatly affect the reproductive output of host plants and thereby influence their distribution and abundance (Louda and Potvin 1995).

Much has been written about the coevolution between phytophagous arthropods and plants, which is a stepwise reciprocal adaptation whereby plants evolve mechanisms to defend themselves against the assault of herbivores and then the arthropods undertake counter adaptations to circumvent the defences (Strong et al. 1984; McEvoy 2002). The process likely began with plants (e.g., crucifers) that evolved mild secondary toxins, which increased in potency as herbivory increased. Once arthropods evolved resistance to the toxins, the plants likely countered with the development of more virulent toxins until this “arms race” led to groups of plants with an array of toxic chemicals and a highly specialized array of herbivores that could feed on them without harm. The presence of secondary plant substances has helped arthropods become specialized and host specific. The phenomenon of host–plant specialization requires that arthropods be able to search for and recognize the hosts even when host plants are uncommon and growing in the middle of species-rich vegetation (Schoonhoven et al. 2007), and the presence of secondary plant compounds helps them to do this.

**Pollination**

Although many of the plants occupying grasslands, such as the grasses, sedges, rushes, and poplars, are pollinated by wind, nearly all the herbaceous plants and shrubs are pollinated by arthropods. Arthropod pollinators help maintain the diversity and viability of populations of wild plants and some agricultural crops in grassland ecosystems. They provide a critical ecosystem service of value to humanity, both monetarily and otherwise (Kearns et al. 1998; Kevan and Phillips 2001; Tscharntke et al. 2005; Klein et al. 2007; Scudder 2009).

Insects began pollinating plants approximately 130–140 million years ago. The mutualistic relationships that developed resulted in many advantages to the angiosperms, including less wastage of pollen and gene flow controlled by the foraging behaviour of the pollinating insects. Sexual isolation among plants has been enhanced by structural features of flowers that rely on foraging behaviour of specialized insects and the reproduction of plants growing some distance from one another (Grimaldi and Engel 2005). Having populations of plants isolated from one another allows more efficient exploitation of resources, reduces interspecific competition, and lessens the possibility of outbreaks of phytophagous insects that specialize on that species. Each of these features is as important in grassland ecosystems today as it was millions of years ago.

Many groups of insects have become pollinators as part of their life history strategies, including syrphid flies, beetles, aculeate wasps, bees, and the adults of moths and butterflies. Some of the grassland pollinators have evolved specialized structures for gathering pollen, such as the pollen baskets on the legs of bees and the plumose hairs on the bodies of bees and the legs of bee flies (Neff et al. 2003). Some of the
moths and butterflies that inhabit grasslands are specialized pollinators responsible for the cross-pollination of prairie plants that could not otherwise reproduce. One of the most intriguing and highly specialized grassland pollinators is the yucca moth, *Tegeticula yuccasella* (Riley) of the family Prodoxidae. This small moth is an obligate pollinator and obligate seed predator of the yucca plant, *Yucca glauca* Nuttall, which in Canada is found at only two sites southeast of the Onefour Agriculture Canada Research Station in the dry hillsides above the Milk River in southeastern Alberta (Addicott 1986). The relationship between the yucca plant and the yucca moth is a textbook example of coevolution; the yucca plant cannot produce seeds without the moth and the yucca moth is likewise dependent upon the yucca plant.

Bees are considered keystone mutualists among the Hymenoptera, as they are essential to the maintenance of diversity in flowering plants (LaSalle and Gauld 1993). Virtually all the species of bees found on the grasslands, and elsewhere, are specialized for feeding on pollen and nectar, making them one of the most ecologically important groups of animals. Bee keeping is an important activity in grassland areas. Honey bees (*Apis mellifera* L.) use a wide a variety of both native and cultivated plants, and in many cases they and the introduced leafcutter bee, *Megachile rotundata* (F.) (Richards 1984), are the principal pollinators of crops where native pollinators are at too low a density or have been eliminated by cropping practices.

Although crucial to the biodiversity and sustainability of grassland ecosystems, arthropod pollinators are increasingly threatened by human activities, including habitat destruction and fragmentation, chemical insecticides and herbicides, and invasions of non-native plants (Kearns *et al.* 1998). Alarming declines in populations of pollinators have been reported in some areas of North America and Europe (Packer and Owen 2001; Kremen *et al.* 2002; Goulson *et al.* 2005; Biesmeijer *et al.* 2006). Even the removal of lands of marginal agricultural value leads to reduced diversity of forage plants and nest sites of natural pollinators and is thought to be a major contributor to the decline in diversity and abundance of native bees (O’Toole 1993; Cane 2001). Fragmentation of grassland habitats is known to negatively impact both the pollinators and the plants they pollinate (Lennartsson 2002). Concerted and coordinated research efforts in pollination ecology are needed, as well as a proactive approach to biological inventories and basic bee taxonomy (O’Toole 1993).

**Natural Enemies of Phytophagous Insects**

All species of herbivorous arthropods feeding on grassland plants and crops are in turn fed upon by a complex of predators and parasitoids. About 25% of all insect species are predatory or parasitic during at least part of their life cycle, as are many species of mites (see Chapter 7) and all spiders (see Chapter 11). Most species of predacious arthropods actively forage, kill, and consume a number of prey during their lifetime. Important groups of terrestrial predacious insects (Triplehorn and Johnson 2005) include ground beetles (Carabidae) (see Chapter 10), rove beetles (Staphylinidae), ladybird beetles (Coccinellidae), blister beetles (Meloidae), lacewings (Chrysopidae), and antlions (Myrmeleontidae) (Neuroptera); assassin and ambush bugs (Reduviidae) (Hemiptera); sphecid wasps (Sphecidae), paper wasps, yellow jackets (Vespidae), and some ants (Formicidae) (Hymenoptera); and robber flies (Asilidae) and hover flies (Syrphidae) (Diptera). Adult dragonflies and damselflies (Odonata) leave aquatic habitats to forage for prey over grassland habitats.
Predacious insects, mites, and Araneae (spiders) are the most visible causes of mortality
of phytophagous arthropods in grasslands. These predators tend to kill many individuals and
therefore are of key importance in grassland ecosystems. Other arthropods of importance
as predators include centipedes (Chilopoda) and harvestmen (Opiliones). Many ecologists
have used observations on predators and their prey to assess the impact of natural enemies
on prey populations, particularly the populations of pests (Speight et al. 1999).

Most of the arthropods that are parasitic on other insects are found in the orders
Diptera and Hymenoptera (Askew 1971). Important families of parasitic flies are bee flies
(Bombylliidae), big-headed flies (Pipunculidae), and tachinids (Tachinidae). However,
parasitic Hymenoptera, particularly the groups Ichneumonoidea and Chalcidoidea, are
abundant and diverse. Parasitic Hymenoptera are one of the most species-rich groups of
Hymenoptera and one of the most speciose groups of insects. The large number of species,
combined with their ability to respond in a density-dependent manner to the population size
of their hosts, makes them essential to the maintenance of ecological balance and diversity
(LaSalle 1993). In many cases, these parasitoids are important in the natural biological
control of key insect pests. However, our knowledge of parasitoid communities in natural
grasslands and agroecosystems is poor (Altieri et al. 1983).

As can be expected, the diversity of parasitoids in agricultural systems is correlated
with the pattern of habitat and structural diversity in the crop systems. As the intensity
of human management increases, the trend is for the biodiversity and size of parasitoid
populations to decrease. Parasitoid complexes of taxonomically and ecologically related
pests tend to be similar in the same crops even when grown in widely separate areas (Altieri
et al. 1983). Even so, a high diversity of parasitoids often remains in natural and semi-
natural grassland ecosystems and can be available as a potential resource for biological
control (LaSalle 1993).

Because many predatory and parasitic arthropod species must repeatedly repopulate
agricultural fields, their success at doing so can be enhanced by increasing the diversity
of plants by undersowing, allowing partial weediness, mulching, reducing tillage, or
retaining natural plots of land nearby (Altieri et al. 1983; Andow 1991). For example,
the diversity of spiders in agroecosystems increases with plant diversity. Spiders are
generalist predators that act against a broad range of prey types, even if prey populations
are small. Hence, their usefulness in pest control lies not only in the quality of the fields,
but also in the plant diversity of the surrounding landscape (Sunderland and Samu 2000).
Spiders tend to remain in diversified patches such that diversification throughout a whole
crop (as in interspersed diversification) enhances their role in pest control.

Below Ground

Relatively little is known about the species of arthropods (e.g., aphids, acari, scarabs, click
beetles, immature planthoppers, noctuid moths) that feed on the roots of grassland plants
(Hooper et al. 2000), even though more herbivory may occur below the soil surface than
above it (Blossey and Hunt-Joshi 2003). Below-ground herbivores such as mites, insect
larvae, and nematodes can have a profound influence on the productivity and species
composition of plant communities (Gange and Brown 2002). Soils also contain diverse
and active meso-and macrofaunal decomposer communities, important players of which
are arthropods. Many soil arthropods function to turn over carbon, mostly below ground
(Curry 1994) and are essential for a fast return of nutrients to primary producers (Moore
Many of the plant–arthropod interactions on aerial and subterranean parts of grassland plants are cross-linked through systemic changes in plant characteristics (Hooper et al. 2000). Above-ground herbivores can influence communities below ground by changing host plant chemistry and dynamics of roots and rhizospheres (Whiles and Charlton 2006). Below-ground herbivory can modify plant characteristics that indirectly influence leaf feeders through carnivorous enemies of the leaf feeders. For example, root feeding by click beetle larvae caused a 10-fold increase in the production of extra-floral nectar, which stimulated visits by carnivorous insects (Wäckers and Bezemer 2003). Below-ground herbivory can also influence the rate and direction of plant succession and plant species richness (De Deyn et al. 2003, 2004).

How soil organisms in grasslands will react to warming brought about by global climatic change is not known. However, warming grassland soils by 3.5 °C in an experimental mesocosm caused significant changes in the composition and trophic structure of the soil fauna community (Briones et al. 2009). Warming decreased the numbers of spiders, insects, and earthworms but increased the diversity of fungivorous mites. The study by Briones et al. (2009) suggested that warming will have a profound effect on root extension and the structure of heterotrophic communities in the rhizosphere, which could alter functional and trophic structure toward a fungal-driven food web and changed vertical stratification. This change could lead to increased soil respiration and N mineralization and a reduction in the incorporation of carbon-rich materials at the surface but an acceleration of soil organic matter turnover in deeper layers.

Management, Conservation, and Restoration of Grassland Arthropods

The one process now going on that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly our descendents are least likely to forgive us.

—E.O. Wilson, 1992

Many people in society, whether they be environmentalists, conservationists, preservationists, or ecologists, are concerned with the demise of grasslands in Canada. Each group has a slightly different perspective on the future of remaining grasslands. According to Hunter (2002), environmentalists are those concerned about the impact of people on environmental quality, whereas conservationists are those who advocate or practise the sensible and careful use of natural resources. Farmers, for example, who practise the wise use of soil and water are considered conservationists. Preservationists advocate that some land and its biota be allowed to exist without significant human interference, whereas ecologists are scientists who study the relationships between organisms and their environment. The authors of this book represent all four groups, as can be seen by the scientific advances explained in their chapters. They are environmentalists because they care and recognize the dangers in deteriorating ecosystems, conservationists because they advocate the wise use of natural resources, and preservationists because they argue for the setting aside of remaining natural and semi-natural grasslands for their intrinsic value and to enable future ecological research. They are ecologists because they understand that complex ecosystems can be sustained only with the majority of their components intact. Studies of arthropod systematics provide the basis for studying the ecology of grasslands.
Conservation Biology and the Need for Action

The field of conservation biology has developed as a result of the realization that we are facing a global extinction crisis (Meffe et al. 1997; Hunter 2002). It is an integrative discipline that focuses on understanding how humans are changing the world and on finding practical solutions that save biodiversity. Conservation biology is based largely on theory from biology, especially ecology and population biology, and draws its energy from the environmental movement and people concerned about the direct effects of environmental change on their own health and well-being. The field also has a philosophical and spiritual foundation and is based on the assumption that conservation of biodiversity will occur when we recognize that humans are part of nature and not separate from it and that it is in our own best interest to protect ecosystems, habitats, and species from extinction.

In some circles, conservation biology has become an applied science with a goal to explore the implications of different land management strategies for the maintenance of biodiversity and ecosystem function and to use this understanding to make recommendations to land managers. This understanding is of particular importance when biological systems such as grasslands are threatened and declining. For example, recommendations for grassland fires based on their impact on biota such as ground beetles (Chapter 10) and spiders (Chapter 11) are important conservation issues.

To check the steady loss of natural habitats, governments, private citizens, and environmental and conservation groups in Canada and the United States have begun to preserve and restore grassland habitats and enhance the goods and services they provide. For example, many cattle farms in the prairies have at least some native to semi-native grasslands and the owners are encouraged to practise grassland conservation. To this end, the World Wildlife Fund, in conjunction with provincial government agencies, environmental organizations, and concerned land owners, has launched the Prairie Conservation Action Plan (Dyson 1996). Useful guides have been published (Trottier 1992) to show private land owners how to retain native grasslands in a functioning condition for the benefit of local biota. In addition, the three prairie provinces have their own action plans for the conservation of prairie resources and of biological diversity for the benefit of current and future generations, as well as for the enhancement of the information base for native prairie and parkland landscapes.

Canada has about 16% of the North American Great Plains (Gauthier and Wiken 2003) and of the grasslands in the Prairie Ecozone remaining in a natural or semi-natural state, Alberta has 43% whereas Saskatchewan has 24.4% and Manitoba 21.0% (Gauthier and Wiken 2003). Alberta has about 33% of the Prairie Ecozone and approximately 1.1% of this is managed for conservation purposes (Gauthier and Wiken 2003). Saskatchewan has about 52% and 9.2% of this is managed for conservation purposes, whereas Manitoba has 15% of the Prairie Ecozone and of this 1.1% is managed for conservation purposes (Gauthier and Wiken 2003). About 3.5% of the Prairie Ecozone of Canada is under some form of conservation area status (Gauthier and Wiken 2003).

The largest block of uncultivated, contiguous native grassland on the prairies is the Canadian Forces Base at Suffield, Alberta, north of Medicine Hat. This military site is 269,000 ha, which is about one half the size of Prince Edward Island. Part of the site, about 45,800 ha, has been declared a National Wildlife Area. About 14,000 wells have been drilled on the Suffield Base and there are requests by oil and gas companies to drill in the National Wildlife Area. Oil and gas development affects grasslands by physically disturbing the
vegetation and soil through the construction of well sites, pipelines, and roads and through secondary effects produced by landscape fragmentation and vehicular traffic, which provides a vector for invasive weeds (Gelbard and Belnap 2003). Since each well site affects about 1 ha, about 5% of the Suffield Base has been impacted by well-site installation.

Another large tract of mostly undisturbed grassland is protected by the Grasslands National Park in southwestern Saskatchewan, near the Montana border. The site was designated a National Park in 1981 and will have an area of about 90,000 ha when completed. Like the Suffield Base, it contains large tracks of mixed grasslands (see Chapter 3). The natural conditions allow uncommon species of plants and animals (e.g., prairie dog, prairie rattlesnake, sage grouse, pronghorn antelope, burrowing owl, short-horned lizard) to inhabit the area. Another large piece of preserved native grassland is Old Man on His Back, a property of 5,300 ha located in southwestern Saskatchewan. Although still a working ranch, about 19% of this land is protected by the Nature Conservancy of Canada (Gauthier and Wiken 2003) and preserved in perpetuity. The previous co-owner, Sharon Butala, described this piece of mixedgrass prairie in her book Old Man on His Back (Butala 2002). Some of the cultivated lands on the property are being converted back to their native state, with the term “native” defined as the historical condition of a piece of land prior to disturbance (Bomar 2001). Another large block of unplowed but grazed grassland occurs at the Agriculture and Agri-Food Canada site at Onefour in the southeast part of Alberta.

The extensive ecological reserves and conservation network in British Columbia established over the years by the Government of British Columbia includes some important grassland areas. These include Churn Creek and the Big Creek Ecological Reserve in the Chilcotin-Cariboo area, the Skihist Ecological Reserve near Lytton, and the Haynes’ Lease Ecological Reserve near Osoyoos (Pitt and Hooper 1994). Citizens of British Columbia, through the Grasslands Conservation Council of British Columbia, the Nature Conservancy of Canada, and The Nature Trust of British Columbia, are actively involved in protecting some of the remaining grasslands in their province. Established as a society in August 1999, the Grasslands Conservation Council of British Columbia is a strategic alliance of organizations, government researchers, range management specialists, ranchers, agrologists, grasslands ecologists, First Nations, environmental groups, recreationists, and grassland enthusiasts. This diverse group shares a common commitment to education, conservation, and stewardship of British Columbia’s grasslands. The mission of the Council is to foster greater understanding and appreciation for the ecological, social, economic, and cultural importance of the grasslands throughout the province, to promote stewardship and sustainable management practices that will ensure the long-term health of grasslands, and to promote the conservation of representative grassland ecosystems, species at risk, and their habitats.

The Nature Trust of British Columbia has acquired land for biodiversity ranches in the South Okanagan and Similkameen region, where the dry grasslands provide habitat for more species at risk than any other area of the province. An estimated 85–90% of this ecosystem has already been lost to agricultural land conversion, urbanization, and residential development (Harding and McCullum 1994). The South Okanagan provides habitat for 30% of the province’s endangered species and 46% of the province’s threatened species, making it a high conservation priority. Much of the remaining intact landscape is at risk from similar development, as well as from habitat degradation as a result of recreational land uses, the spread of invasive species, overgrazing, and alteration of the natural disturbance regime because of fire suppression (Austin et al. 2008). A Desert Centre run by the Osoyoos Desert
Society has been established on protected land just to the north of Osoyoos. The Osoyoos Indian Band also operates an interpretive centre on protected land on their reserve.

Of all the types of natural grasslands once found in western Canada, the tallgrass prairie of southcentral Manitoba has suffered the most. Before the arrival of European settlers, the Red River Valley south of Winnipeg was a vast expanse of tall grasses covering about 6,000 km². However, the richness of tallgrass prairie with its deep fertile soils resulted in its quick conversion to fields of grain. Today less than 1% of its former area remains and much of this is threatened by the advance of aspen, oak and other trees of the Manitoba Lowlands to the east.

In 1987, the Manitoba Naturalists Society launched a Tall-Grass Prairie Conservation Project to locate and survey surviving remnants of tallgrass prairie. Only a few sites were discovered, most less than a hectare in size, with the largest tracts near the towns of Tolstoi and Gardenton in the southeast. Then in 1989, the Critical Wildlife Habitat Program of Manitoba Natural Resources, a cooperative program involving seven conservation organizations, began securing lands for a prairie preserve (see Fig. 21 in Chapter 3). The Nature Conservancy of Canada has also taken a lead role in a partnership of environmental groups dedicated to securing and restoring this important prairie remnant to its original state. Today, over 2000 ha of tallgrass prairie are protected in several blocks of land forming the Manitoba’s Tall Grass Prairie Preserve. The Preserve houses Canada’s only populations of the rare Poweshiek skipper *Oarisma poweshiek* (Parker) and the endangered western prairie fringed orchid (*Platanthera praeclara* Sheviak & Bowles). The Agassiz Interpretive Trail in the Preserve allows visitors to discover the richness of this prairie habitat, for which a detailed biodiversity assessment continues.

The Criddle/Vane Homestead (see Fig. 19 in Chapter 3) in southwestern Manitoba, near Aweme, about 40 km southeast of Brandon, is the location of the first entomological laboratory in western Canada (see Fig. 20 in Chapter 3). This 130 ha site became Manitoba’s 79th Provincial Park on February 24, 2004 to preserve and protect the heritage value of the former homestead and its mixed grass and tallgrass prairie. A Criddle/Vane Homestead Heritage Committee has raised awareness of the entomological significance of Aweme and has restored Norman Criddle’s laboratory.

Targets for restored grasslands are ideally set with respect to known reference points. Remnants are considered any patch of native vegetation in which most or all of the original biota remains; they have often been called habitat islands and have been the subject of considerable debate in the literature (Saunders et al. 1991). Fragmentation of the landscape produces these patches of remnant vegetation, which are usually surrounded by a matrix of different vegetation and/or land uses. Fragmentation, caused by roads for example, affects our perception of remaining grasslands because it increases the edge-to-area ratio of surviving patches, leading to smaller effective undisturbed interiors. These environmental differences can lead to several direct and indirect effects on arthropod fauna, including a high diversity of exotic species and a low diversity of native species.

Fragmented populations may be genetically isolated, reduced in size, and susceptible to inbreeding and extinction. Several reviews attest to these detrimental effects (e.g., Saunders et al. 1991). The loss of connectivity of remaining grassland ecosystems will likely limit the ability of species to shift their distributions in response to climate change. Two primary effects of fragmentation are an alteration of the microclimate within and surrounding the remnants and the isolation of each area from other remnant patches in the surrounding landscape. Fragmentation results in fluxes in radiation, wind, and water, which influence arthropod fauna. The time since isolation, the distance between adjacent
remnants, and the degree of connectivity among them are important determinants of the response by arthropods to fragmentation and the diversity of fauna within them (Saunders et al. 1991). Gauthier and Wiken (2003) call for the identification and monitoring of fragmented grasslands since some patches may perform a more significant ecological function as stepping-stones for certain species than others.

Besides protecting the ecological role of arthropod fauna within remnants, we need to preserve them for possible use as introductions in grassland habitats that are being restored or reconstructed. Restoration of grasslands involves habitat treatments that use human-intensive management, such as fire, weeding, and brushing, to enhance a prairie habitat, whereas reconstruction involves habitat treatment that uses intensive management, as well as the introduction of prairie plants, to replace an agricultural or abandoned field (Bomar 2001). Some managed grasslands include the preservation of arthropods (Oomes and van der Werf 1996; Morris 2000; Cook and Holt 2006).

It is also possible to take former grasslands currently under cultivation and return them to a somewhat natural state (Lindborg 2006). The restoration of any ecosystem altered by human activities is difficult and, in most cases, we lack the ecological knowledge. The acid test of our knowledge of the form and function of grassland ecosystems occurs when we try to recreate natural ecosystems that resemble those that occurred before humans arrived (Bradshaw 1993; Collinge 2000). Little else better illustrates the extent of our understanding of an ecosystem than trying to build or emulate one! Ecosystems resembling grasslands have been built on inhospitable habitats that include metalliferous mine tailings near Sudbury, Ontario (Bagatto and Shorthouse 1999), which suggests that they can be constructed in any of the degraded grassland areas in Canada.

Grasslands in the process of restoration may not at first resemble the natural ecosystems nearby, but in time they will become functional, and more natural communities will appear. It is unfortunate that the perspective of First Nation’s people on the management of grasslands, and their knowledge of conditions of grasslands in the past, has in most cases been lost as attempts are made to restore grasslands (Blackstock and McAllister 2004). When the European settlers arrived along with their cattle that needed water, fencing, and the cultivation of grasslands for hay and grains (Blackstock and McAllister 2004), First Nations people lost their free access to the grasslands of southern British Columbia (Lea 2008) and the prairies. By 1900, most of the perennial grass prairie was replaced with low-growing, grazing-resistant introduced bluegrass, forbs, shrubs, and weeds (Gayton 2003). As a result, the culture of First Nation’s people changed from one of gathering sustenance to marginalization, and their intimate knowledge of grassland form and function was lost.

Relatively few studies of ecosystem conservation or restoration projects include arthropods, but this should change because arthropods often affect the success of conservation or restoration projects focused on other species in integrated communities. Arthropods return quickly to restored habitats, and there is no doubt they would do the same in all restoration attempts in grassland ecoregions in southern Canada. Grasslands have been restored in the United States from sites overgrown with trees by using remnant biota found along roadsides after tree removal and burning (Stritch 1990). However, convincing the public of the value of such restorations is often a challenging task (Davenport et al. 2007). An ideal model is the Curtis Prairie in Madison, Wisconsin, which is the oldest restored prairie in the world. Initiated by Aldo Leopold in 1934 to recreate the natural habitats of Wisconsin, about 38 ha of former cornfields and overgrazed woodlands have been restored to prairie, with most of the native species re-established.
Similar successes are possible all across southern Canada, if all grassland biologists, especially those studying arthropods, become ambassadors of restoration and preservation.

**Hohhot Declaration**

Today, as throughout history, temperate grasslands play an essential role in the survival and livelihoods of millions of people around the world. Grasslands provide agricultural goods, support significant numbers of wildlife (including many species at risk), and increasingly are recognized as ecosystems that provide vital functions to society, such as the sequestration and storage of carbon. In the face of global climate change and economic pressures to support local, sustainable agriculture, governments around the world are urged to heed the call of international experts to protect grasslands. In July of 2008, researchers interested in the well-being of grasslands around the world held an International Grassland and Rangeland Congress in Hohhot, the capital of Inner Mongolia, China. A highlight of the Congress was the release of the Hohhot Declaration, in which grassland and rangeland experts appealed to governments at all levels to take action and stop the fragmentation, development, and degradation of grasslands worldwide. The Hohhot Declaration was the result of a Canadian-led World Temperate Grasslands Conservation Initiative workshop organized by the Grasslands Task Force of the International Union for Conservation of Nature, in which participants from 14 countries on five continents began to forge a global conservation strategy for the world’s temperate grasslands. “The outcome of this workshop is very powerful,” said Bruno Delesalle, one of the participants and the Executive Director of the Grasslands Conservation Council of BC. “The message agreed to by consensus states that in the face of global climate change, governments and industry must recognize the important role grasslands play in supporting ecological, social and economic sustainability. We just can’t afford to see them developed, degraded or lost.” The Declaration clearly states that the global community must act quickly to ensure appropriate management and conservation of grassland resources and, in turn, the ecological goods and services they provide. “Grasslands are a vital part of our past, present and future,” stated Delesalle.

**Conclusions**

Among the many objectives in writing this book was an attempt to draw attention to the diverse roles of grassland arthropods and explain how they are necessary for the functioning of natural and agroecosystems. It is of concern that an inventory of our grasslands biota, especially the arthropods, has not been undertaken. Although some groups such as the butterflies, grasshoppers, carabid ground beetles, tiger beetles, and selected Hemiptera have been surveyed, almost nothing is known about the biodiversity of the remaining taxa. As is the case in other ecosystems, estimates of the status of native arthropod biodiversity in grasslands are often confounded by limitations in knowledge. It is difficult to estimate losses in arthropod biodiversity when about half of the North American species wait description (Samson and Knopf 1996). A census of the biodiversity of arthropods in the remaining grasslands in Canada is the first important step and has been an important priority of the Biological Survey of Canada.

More detailed faunal surveys are needed encompassing all groups, particularly those neglected to date such as spiders, mites, apocritan parasitoids, and below-ground and litter-
dwelling fauna. Basic biological attributes such as life history strategies, feeding habits, and habitat affinities are lacking for nearly all the grassland fauna of Canada and must be addressed. More effort is needed in quantifying the ecological role of grassland arthropods, especially in terms of ecosystem-level processes and functions such as decomposition, nutrient cycling, and primary production (Whiles and Charlton 2006).

Grassland biologists should encourage public understanding that arthropods provide an invaluable range of ecosystem services that benefit humans, such as pollination (Biesmeijer et al. 2006), decomposition of organic matter (Gullan and Cranston 2005), enemies of pests (Quicke 1997), and prey in food webs (Hunter and Price 1992). As stated so aptly by Wilson (1987), arthropods are the “little things that run the world” as they direct the flow of energy and cycling of nutrients through food webs. Losey and Vaughan (2006) estimated that the annual economic value of just four ecological services provided by insects—dung burial, pest control, pollination, and wildlife nutrition—was $57 billion in the United States based on projections of losses if insects were not functioning at their current level. It is unfortunate that some species of arthropods become pests in agroecosystems. This commonly results in a negative view, even though the number of “pests” is but a small fraction of the total number of grassland arthropod species (Speight et al. 1999; Schowalter 2006). Further, the occurrence of pestiferous arthropods makes it difficult for biologists to convince the public that insects and their relatives deserve to be targets of conservation (Hunter and Hunter 2008). Dialogue must be fostered between those who currently own grasslands and those who recognize that the retention of at least a small part of these ecosystems in a natural or semi-natural state will be of benefit to human well-being.

A common message coming from grassland biologists, including those who authored the pages of this book, is that as much as possible of the few remaining natural or semi-natural grasslands in British Columbia, the prairies, and southwestern Ontario must be saved and their ecological functions be allowed to persist. If action is not taken soon, there likely will be countless centinelan species, a term proposed by Wilson (1992) for flora and fauna that become extinct before they are described and named. Thus, it is hoped that the information assembled here will help foster the need for conservation and preservation of remaining grasslands and also encourage the return of some only partially altered grasslands back to a semi-natural condition.

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References


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