# Grasshopper Outbreaks

Insects and the ancestors of grasshoppers have been on earth a long time. Hexapod (six-legged) insects are believed to have split off from aquatic crustaceans during the Silurian period around 410 million years ago (mya). The oldest fossil insect is from the Devonian period around 407 to 396 mya. Insect flight is thought to have developed through several stages of adaptive intermediate steps involving aquatic insects skimming on water with each stage providing less contact with the water until water was no longer needed. The shorthorned grasshoppers (Caelifera) and the longhorned crickets (Ensifera) split from each other near the Permian-Triassic boundary around 251 mya (Anissimov 2013). Flowering plants (Angiosperms) started to evolve during the Mezozoic Era around 120 mya. The modern Acrididae family of grasshoppers started development during the Upper Cretaceous around 99 mya. Fossil grasshoppers from the Cretaceous have external anatomical characteristics similar to modern grasshoppers which is homologous to the phylogenetic pattern followed by cockroaches (Blattaria) from the Cretaceous to modern cockroaches (Manske and Lewis 1990). The Cretaceous "grasshopper" has a retroactive name because they did not live in grassland habitats and did not eat grass food plants which came much later. The grasshopper subfamilies of Gomphocerinae, Melanoplinae, and Oedipodinae developed during 90 to 50 mya. Near the end of the Eocene epoch around 34 mya, the global climate cooled resulting in reduced forest ecosystems and increased open savannah ecosystems that later developed into grasslands (Chintauan-Marquier et al. 2011, Gomez et al. 2012, Anissimor 2013, Anonymous 2013). The major climate change in the Eocene resulted in the development of modern grasses between 30 and 20 mya. The grasses (Poaceae) and orchids (Orchidaceae) are advanced angiosperms that were among the last families to evolve. During the period of 30 to 20 mya, modern native grasses, rhizosphere organisms, large grazing mammalian graminivores, and modern grasshoppers coevolved and developed complex interactive processes that have improved mutual survival on grassland ecosystems.

Grasshoppers evolved as a natural and integral component of rangeland ecosystems. Grasshoppers are an important source as part of the food chain for numerous rangeland birds, small mammals, reptiles, amphibians, arachnids, and other insects (Watts et al. 1989). Grasshopper populations usually remain at densities that can be supported by the ecosystem and, at these low population densities, grasshoppers are not a problem. However, periodically, grasshopper populations increase to outbreak levels. Grasshopper outbreaks greatly reduce the quantity of forage available for livestock causing economic losses due to reduced livestock stocking rates and weight gains and to the additional costs for chemical insecticide treatments (Watts et al. 1989). Ecological losses occur from grasshopper outbreaks by the removal of greater quantities of leaf material than can be tolerated by grass plants resulting in degraded range condition and reduced wildlife habitat.

Changes in grasshopper density have often been speculated to be directly related with changes in weather conditions. Weather variables are correlated with grasshopper population dynamics, however, weather variables are not the direct cause and effect factors that change grasshopper population numbers (Fisher et al. 1996b, Belovsky et al. 1996, Belovsky 2000). The mechanisms that drive grasshopper population numbers are changes in plant production and nutritional quality, changes in grasshopper growth and development rates, and changes in predation, parasitism, and pathogen infection rates. Grasshopper growth and develvment rates are determined by the nutritional quality and quantity of the food plants and by accessibility to thermal heat units from the sun. Grasshopper population numbers are affected by the mortality rate caused by natural enemies. The quantity of predators, parasites, and pathogens are also determined indirectly by environmental conditions and by the abundance of available prey species.

Grasshopper populations in arid regions, as in the intermountain sagebrush-bunchgrass range (Fielding and Brusven 1996a, b) and the southern short grasslands of Arizona and Colorado (Nerney 1958, Nerney and Hamilton 1969, Capinera and Sechrist 1982, Bock et al. 1992, Onsager 1996), are limited by the quantity of available nutritious food plants. The grasshopper populations in these arid areas are usually suppressed during growing seasons with low or normal precipitation, and tend to increase during years with above normal precipitation. Access to radiant heat from the sun is not limiting the grasshopper population growth at any time in these arid regions because of the relatively low vegetation canopy, however, the available food supply usually limits the grasshopper density except during years with greater than normal precipitation and above normal grass herbage production.

Grasshopper populations in the semiarid, subhumid, and humid regions of the Northern Plains are not limited by the quantity of available nutritious food plants but are limited by the accessibility to thermal heat units from the sun because of the shading effect caused by the relatively tall vegetation canopy. Grasshopper populations in the Northern Plains are usually suppressed during growing seasons with normal and above normal precipitation and normal and above normal grass herbage production. The greater quantities of grass herbage biomass produced and the taller vegetation canopy in the Northern Plains, compared to the grass herbage production and vegetation canopy in the intermountain and desert southwest regions, limit access to radiant heat from the sun except when low precipitation or heavy grazing by livestock reduce the vegetation canopy on native grasslands or when double use, such as grazing and haying, during one growing season reduce the vegetation canopy on domesticated grasslands. Generally, grasshopper populations increase when vegetation canopy height decrease and the highest infestations occur when ground cover is reduced to less than 40% of potential (Onsager 1987, 2000).

Pestiferous rangeland grasshopper outbreaks develop through two processes (Belovsky, Lockwood, and Winks 1996, Lockwood, Brewer, and Schell 1996). The **eruptive outbreak** increases rapidly over one to two years in a relatively small area or "hotspot" and then expands outward into larger areas. The **gradient outbreak** starts with low numbers throughout a region, then gradually increases in numbers over several years, which is followed by a growing season of marked increase of 3 to 5 times the previous years density. The extreme increase in grasshopper numbers during the outbreak growing season usually appear to have resulted from greater longevity and thus greater egg production by adults in the preceding year (Pfadt 1977). Grasshopper outbreaks on rangeland consist of 3 to 4

species, and usually not more than 5 different species; only rarely does an assemblage consist of one species. These outbreak grasshoppers species compose most of the population and makeup the dominate, codominate, and subdominate components of the assemblage. Several other grasshopper species also occur in the outbreak area and compose a small portion in the assemblage, however, their population densities do not increase greatly (Belovsky et al. 1996). All of the grasshopper species comprising the assemblage contribute to the economic forage losses and the ecological degradation.

Vegetation canopy reduction or removal increases solar radiation and day degree heat units at the soil surface and increases air flow over the ground, which increases both the soil and air temperatures and decreases relative humidity for grasshoppers. Increased solar radiation to the soil increases day degree heat units that accelerate embryonic development in the egg that results in earlier hatch. Vegetation canopy reduction improves basking sites that hasten body warm up of nymphs and adults that results in increased metabolic rates and increased growth and development rates that shorten instar stages and adult maturation time. Greater solar radiation, higher soil and air temperatures, and lower humidity in grasshopper microhabitat has debilitating effects on pathogens, resulting in lower mortality rates, which increases the number of nymphs reaching adult stage, and increases the longevity of adults that promotes greater egg production.

The crucial factor for successful cultural management of grasshoppers in the Northern Plains is the stimulative manipulation of the abundant herbage biomass production and the maintenance of relatively tall vegetation canopy so that the growth and development rates of grasshopper eggs, nymphs, and adults are greatly inhibited as a result of restricted access to radiant day degree heat units from the sun.