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*Editorial*

# Locusts and Grasshoppers: Behavior, Ecology, and Biogeography

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Locusts and grasshoppers (L&G) (Orthoptera: Caelifera, Acridoidea) are an essential component of both, healthy, and disturbed grassland ecosystems. These insects are abundant in natural and anthropogenic habitats (rangelands, wetlands, agricultural fields, lawns, etc.). They stimulate plant growth, participate in nutrient cycling, and play important role in food chains [1–5]. Some grasshoppers are proposed as ecological indicators of ecosystem qualities and efficacy of ecological networks [6]. On the other hand, when their populations grow to catastrophic dimensions, L&G are among the most devastating enemies of agriculturists. Outbreaks of locusts such as *Schistocerca gregaria* (Forskål, 1775), *Nomadacris septemfasciata* (Serville, 1838), *Locusta migratoria* Linnaeus, 1758, *Calliptamus italicus* (Linnaeus, 1758), *Dociostaurus maroccanus* (Thunberg, 1815), *Chortoicetes terminifera* (Walker, 1870), and many abundant grasshopper species continue to occur on all continents except Antarctica and affect the livelihoods of one in every ten people on Earth. Such L&G outbreaks are now better controlled and their frequency and size have been reduced with the application of preventative strategies [7, 8]. However, invasions still persist. During the outbreak of the Desert locust *S. gregaria* in Africa in 2003–2005, over eight million people suffered from severe 80 to 100% crop losses [9]. To combat the locust swarms, 13 million hectares in 22 countries on three continents were treated with broad-spectrum neurotoxins. Such transcontinental operation, including the food aid for affected population, cost over half a billion US dollars to the world community [10].

Losses to L&G are not limited to crop and rangeland destruction. Besides the economic damage and its subsequent negative social impact, L&G outbreaks may seriously alter ecological processes across landscapes (e.g., carbon and water cycles). The rapid loss of vegetation cover may result in soil erosion and increased runoff. L&G can also destroy food sources for many animals and thus affect biodiversity; such effects may be particularly pronounced in isolated insular ecosystems [11]. Large-scale L&G control programs can also affect biodiversity, including that of nontarget grasshoppers [12]. Despite decades of intensive research, the mechanisms underlying L&G population dynamics (and for locusts: phase transformation) are not fully elucidated. Only recently, significant advances were made in our understanding of L&G behavior and ecology, particularly individual and group movement, nutritional requirements, and biochemical mechanisms underlying the transformation between solitarious and gregarious locust phases [13–15]; see also review in [16].

Besides the notorious pests, this group of insects includes many understated rare species which require protection [17–19]. To complicate the picture, following landscape changes induced by human agricultural activities, some economic pests may become exceedingly rare [20]. On the other hand, many orthopteran species benefit from human-induced landscape changes and increase their abundance [18, 21]. Disturbed and new habitats can be important for spreading and living of some native and alien grasshopper forms [18, 21, 22]. At the same time, many of rare grasshopper species are threatened by anthropogenic influences, such as overgrazing and ploughing [18]. However, in various areas, such as temperate Eurasia or in Tropical Madagascar, several centers of orthopteran diversity and endemism overlap with areas of frequent L&G outbreaks [23–25]. This means that problems of plant protection and conservation biology should be solved on the complex basis of a holistic approach. However, it is hardly ever the case; pests and rare species are usually studied separately, and their possible relationships are not explored.

Although the general patterns of grasshopper distribution are described for different regions [26–28], the main factors and processes determining grasshopper diversity patterns at different scales are still under discussion. Importance of temperatures and precipitation is evident, but the distribution of many species, populations, and assemblages could not be explained by macroclimatic factors only [29]. This means that the role of other factors and processes should be investigated more thoroughly. At a regional level, it is possible to establish the general pattern of regional biodiversity and explain how the spatial distribution of populations permits species with various origins and different ecological preferences to coexist [30].

An example of this approach is the opening article for this special issue of Psyche, in which M. G. Sergeev reviews distribution patterns of over 130 species of grasshoppers and their kin in the boreal zone. Grasshoppers and their relatives occupy there almost exclusively open habitats, such as meadows, mountain steppes and tundras, clearings, openings, bogs, and stony flood plains. The boreal orthopteroid assemblages exhibit low species diversity and abundance. Based on the biogeographic analysis, the author concludes that relationships between the faunas of the Eurasian and North American parts of the boreal zone are relatively weak.

Local grasshopper distribution patterns have been discussed since the beginning of the 20th century. Possible relationships between grasshopper diversity, plant species composition, and habitat structure have been discussed for many decades. The paper of D. H. Branson (second in this special issue) provides an example of such studies. The author found these relationships too complicated for simple explanations. The type, level, strength, and complexity of these relationships may be determined not only by local but also by regional patterns. Consequently, to evaluate general trends in grasshopper diversity one should study all main regions and ecosystems in the same manner. This idea may serve as a basis for an ambitious regional study.

The third paper of the special issue is devoted to a complex terminological issue. Acridologists have used a variety of terms to describe groups of grasshoppers, including assemblage, community, guild, and population. This terminological diversity has raised the question of whether one of these descriptors is the correct one. The author, J. A. Lockwood, argues that a term is correct if it accurately reflects the conceptual framework of the investigator and effectively communicates this perspective to others. He describes the contexts in which the most common terms are appropriate.

In the next paper, O. Olfert et al. investigate the impact of climate changes on distribution and relative abundance of a pest grasshopper of major economic importance in North America, *Melanoplus sanguinipes*. Various scenarios of climatic changes were used to parameterize a bioclimatic model of this species. Compared to predicted range and distribution under current climate conditions, model results indicated that *M. sanguinipes* would have increased range and relative abundance in more northern regions of North America. Conversely, model output predicted that the range of this crop pest could contract in regions where climate conditions became limiting. However, some caution has been expressed by authors. The impact of biotic factors such as natural enemies should also be considered, and bioclimatic modeling of grasshopper populations will surely benefit in the future from a multitrophic approach (host plants-grasshoppers-natural enemies).

The fifth paper of this special issue by H. Song reviews the current state-of-the-art regarding locust phase polyphenism in species other than the two model locusts. Although the mechanisms of locust phase transformation are relatively well understood for the Desert locust and the Migratory locust, they remain largely obscure in nonmodel locust species. The author found similar density-dependent phenotypic plasticity among closely related species. He emphasized the importance of comparative analyses in understanding the evolution of locust phase and proposed a phylogeny-based research framework for future analyses.

In the next paper M. Lecoq et al. present a typology quantifying density-dependent color change in the Red locust nymphs. This information can contribute to improving the reliability of the data collected by the National Locust Centers when surveying this major pest. The authors, in Madagascar, sampled hoppers from several populations of different density and measured the color of different body parts as categorical variables. They found that color change is positively correlated with population density. This study is an important contribution to our knowledge of locust coloration in the field, for which there is currently a weaker understanding than that for laboratory populations.

The seventh paper of this special issue by S. O. Ely et al. discusses the diel behavioral activity patterns of solitarious Desert locust adults. The authors found that the insects were more attracted to volatiles from potted *Heliotropium ovalifolium* in scotophase than in photophase. The attraction towards the host plant odors, in both photophase and scotophase, concurs with previous observations on locust oviposition preferences near these plants.

In the eighth paper, R. B. Srygley and S. T. Jaronski report experiments with *Beauveria bassiana* (Fungi: Ascomycota), an entomopathogenic fungus that serves as a biological control agent of Mormon crickets *Anabrus simplex* Haldeman (Orthoptera: Tettigoniidae) and other grasshopper pests. They demonstrated an immune response of infected Mormon crickets and concluded that circulating phenoloxidase may be an important enzymatic defense against *Beauveria* infection, and that it is associated with attempted clearing of *Beauveria* blastospores and hyphae from Mormon cricket hemolymph.

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