The highest diversity of galling insects: Serra do Cipó, Brazil

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Abstract. During the past decade many studies have been carried out on the distribution of gall-forming insects along gradients of temperature, humidity, elevation, and latitude. Over 300 localities have already been sampled around the world representing numerous vegetation types such as shrubland, desert, chaparral, cerrado, savanna, tropical rain forest, taiga, tundra, and pine forest using sound and field-tested methods. The peak of species richness has been found at low and dry elevations, in areas of sclerophyllous vegetation. Nevertheless, gallers are most species rich and abundant in dry habitats. Among all habitats studied, the Brazilian cerrado has the richest fauna of galling insects. At 900 m altitude in a cerrado area at the base of the Serra do Cipó in south-east Brazil, we found the richest galling insect fauna (forty-six species in a census of forty-five trees, 100 shrubs and 1000 herbs per site). At this elevation, the soil is rocky and sandy, nutrient-poor, and the vegetation is dominated by woody, sclerophyllous plants, with few herbs. The plant most attacked was Baccharis concinna (Asteraceae) which supported fifteen galling species.

Key words. Biogeography, cerrado, diversity, insect galls, richness, savanna, Serra do Cipó.

INTRODUCTION

The question "how many species are there?" is central to evolutionary ecology and conservation biology. This question has endured for more than 160 years, since it was first raised by Westwood (1833). Estimates of species diversity have been made for many plant and animal taxa, but detailed and long-term studies have been carried out for only a few groups. Perhaps the major problem being faced is the variation in sampling procedures, which can impair comparisons across taxa and biogeographical regions. Hence, instead of describing absolute numbers of species, it is necessary to develop sound and replicable sampling techniques so that numbers can be compared with confidence across habitats and microhabitats (Erwin, 1991). Data...
must also be obtained directly from the field in a context in which the same questions can be asked repeatedly, and enabling as such global evaluations (Fernandes & Price, 1988; Erwin, 1991). Some guilds of arthropods have been sampled in this way (see Erwin, 1983, 1988), although to obtain more accurate estimates of biodiversity on earth, these studies need to be extended to a greater number of insect groups.

During the last 10 years, numerous studies have been conducted to examine the patterns of gall-forming insect diversity in several biomes. Samples have been concentrated in Australia, Brazil, Canada, Costa Rica, England, Fiji, Finland, Israel, Japan, Mexico, Panama, Russia, South Africa, and the United States. More than 300 localities have been sampled representing a variety of vegetation types including shrubland, desert, chaparral, cerrado, rupestrian field, African savanna, tropical rain forest, taiga, tundra, and pine forest (Price et al. 1996). Hence, galling diversity can be compared in numerous latitudes (from 0° to 60[N and 45° S), and elevations (from 0 m at sea level to 4000 m).

Because of the peculiar way of living most of the life time immersed in the tissues of the galls, it is difficult to evaluate the numbers of adult life forms of galling insects. In addition, many insect gallers live only few days (see Mani, 1964) and it is difficult to classify the species if host plant records are not available. Such a situation has been documented in the family Cecidomyiidae (Diptera), the most common galling taxon (Gagné, 1989, 1994). Thus, censuses of galling insects are difficult to obtain by using conventional sampling techniques (light traps, logging).

Here we report on solid and field-tested methods of gall sampling which have been used by us since 1984, and provide the first estimate of a highly diverse habitat of galling insects in the world.

In our galling insect diversity surveys two methods were used. In method 1, transects 10 m wide were staked out at each sample site, and subsequently searched for galls above ground until forty-five trees, 100 shrubs and 1000 herbs had been sampled. These numbers were defined through the species-area curves described in Fernandes & Price (1988) to obtain an asymptotic accumulation of gall species. The difference in the numbers of samples of trees, shrubs and herbs is an attempt to minimize the influence of the structural complexity of plants on the richness of insect communities (see Strong, Lawton & Southwood, 1984). Sampling method 2 consisted of a one-hour census, walking through an area and examining plants carefully, searching for galls. In both methods, galling insects and their host plants were recorded as morphospecies (Price 1991). A detailed description and comparison of these methods can be found in Price et al., (1996). The Brazilian cerrado has found to have the richest fauna of galling insects based upon the survey method 1.

THE RICHEST HABITAT

The cerrado comprises an area of 1.8 million km² and is highly variable in its plant composition and structure (Eiten, 1978). Cerrado is a complex woodland and grassland vegetational province in central Brazil that presents a xeromorphic aspect with Vochysiaceae, Annonaceae, Myrtaceae, Asteraceae, and Leguminosae being the most representative plant families (Giulietti & Pirani, 1988; Oliveira-Filho & Ratter, 1995). This region has a mean annual rainfall of 1500 mm, and the cerrado occurs on infertile and deep soils called latosols (Hueck, 1972). Patches of richer soils are covered by mesophytic forests, and rivers and streams are bordered by gallery forest. The cerrado vegetation sampled along the Espinhaço mountains in Minas Gerais State were in the localities: Lagoa Santa, Serra do Cipó, Caraça, Cristália, Grão Mogol, Belo, Minas Novas, and Turmalina, along an altitudinal gradient ranging from 800 m (in Lagoa Santa) to 1700 m (in Serra do Cipó). We sampled insect galls on all major cerrado habitat types: campo limpo, campo sujo, cerrado (stricta sensu), cerradão, rupestrian fields, ‘buriti forest’, and gallery forest.

In the Espinhaço mountains the vegetation is dominated by cerrado and high altitude rupestrian fields. The sclerophyllous vegetation in lithosols in the mountains are called rupestrian fields (rocky fields). In the Serra do Cipó, the high altitude rupestrian fields occur from 900 m (intermixed with cerrado until 1100 m) to the mountain top at approximately 1700 m altitude. The flora is largely endemic and highly diverse (Giulietti, 1996). The woody plants of rupestrian fields may form groves of open or even closed scrub over outcropping hard bedrock (Eiten, 1978; Goodland & Ferri, 1979). To enable a broader view on galling distribution and richness, other Brazilian forest formations were also sampled during the study: Atlantic forest, Amazonian rain forest, caatingas (thorny and scrubby vegetation), campina vegetation along the Rio Negro, and coastal dune vegetation locally called restinga.

At an altitude of 900 m in a cerrado area at the base of the Serra do Cipó, the high altitude rupestrian fields were sampled. The woody plants in these fields are characterized by having long, straight trunks, and some species can reach heights of up to 25 m. The vegetation is dominated by high altitude rupestrian fields and gallery forest. The cerrado comprises an area of 1.8 million km² and is highly variable in its plant composition and structure (Eiten, 1978). Cerrado is a complex woodland and grassland vegetational province in central Brazil that presents a xeromorphic aspect with Vochysiaceae, Annonaceae, Myrtaceae, Asteraceae, and Leguminosae being the most representative plant families (Giulietti & Pirani, 1988; Oliveira-Filho & Ratter, 1995). This region has a mean annual rainfall of 1500 mm, and the cerrado occurs on infertile and deep soils called latosols (Hueck, 1972). Patches of richer soils are covered by mesophytic forests, and rivers and streams are bordered by gallery forest. The cerrado vegetation sampled along the Espinhaço mountains in Minas Gerais State were in the localities: Lagoa Santa, Serra do Cipó, Caraça, Cristália, Grão Mogol, Belo, Minas Novas, and Turmalina, along an altitudinal gradient ranging from 800 m (in Lagoa Santa) to 1700 m (in Serra do Cipó). We sampled insect galls on all major cerrado habitat types: campo limpo, campo sujo, cerrado (stricta sensu), cerradão, rupestrian fields, ‘buriti forest’, and gallery forest.

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of the Serra do Cipó we found the richest galling insect fauna (forty-six species using method 1). At this elevation, the soil is rocky and sandy, and the vegetation is dominated by woody, sclerophyllous plants, with a few herbs. The richness of galling insects in communities with these characteristics is known to be very high (Price, 1991; Lara & Femandes, 1996). The plant most attacked, *Baccharis concinna* (Asteraceae), supported fifteen galling species. To our knowledge, this plant supports the richest insect galling community in the neotropics (Femandes *et al*., 1996b).

Gallers are the most common, and perhaps most important herbivores in this vegetation type. The influence of gallers on the population dynamics of their host plants and habitat dynamics is under investigation, but we feel that gallers could drive many important processes in this type of ecosystem. For instance, the field woodpecker, *Colaptes campestris*, was frequently seen to feed on the woody galls caused by the weevil *Colabismus citellae* (Coleoptera: Curculionidae) on *Solanum lycocarpum* (Solanaceae). After the emergence of the galling insect, galls are often occupied by other species such as ants, spiders, termites, and even small frogs (Mani, 1964). The hairs of many galls are often used by cerrado birds to construct their nests (e.g. the hummingbird *Eupetomena macroura*). Gallers were also noted to be the most common herbivores in a similar habitat, the campina vegetation along Rio Negro, Amazonia (D. H. Janzen, pers. comm.; Femandes & Price, 1991). Although not described, more than 90% of the cerrado galling species were new to science, and of these a large proportion were endemic to this vegetation type (G. W. Femandes, unpub. data).

In addition to the description of the distribution patterns, we found some interesting characteristics of this insect guild. Comparisons of galling richness along altitudinal and latitudinal gradients have shown that the peak of species occurs at low and dry elevations, mainly between 25 to 38°N or S, in areas covered by sclerophyllous vegetation (Price, 1991; Price *et al*. 1996). Comparisons between dry and humid habitats also showed that gallers were most species-rich and abundant in dry habitats (Femandes & Price, 1988, 1991; Femandes & Lara, 1993; Femandes, Paula & Loyola, 1995; Femandes *et al*., 1996a; Lara & Femandes 1996).

Despite its importance, representing 22% of Brazilian vegetation (Hueck, 1972), the cerrado ecosystem has been severely endangered for the expansion of agriculture, eucalyptus plantation, and the production of charcoal. The cerrado vegetation is of enormous interest to ecologists because of the richness and high endemism of the plants and animal species (Vanzolini & Heyer, 1987). Within the cerrado domain, the high altitude rupestrian fields are unique in their degree of endemism (see Giulietti, 1996).

Despite sampling in the most diverse high altitude rupestrian fields, and covering the major cerrado formations, the area covered by the census is small compared to the area of the cerrado in Brazil. Nonetheless, the primary goal of this study will have been met if students pursue and broaden our knowledge on the richness of gallers and generate questions which attempt to unravel the ecological mechanisms and biogeographical relationships involving gallers, host plants and habitats.

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REFERENCES


