

Diversity of Galling Species Along Two Successional Gradients

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Sites: Indiana Dunes National Lakeshore, Indiana, and Mud Lake Nature Preserve, Michigan

Key words: *biodiversity, bog lakes, galls, insect-plant interaction, sand dunes, successional gradient.*

Abstract

Water and nutrient availability, plant species number and plant biomass have been considered major forces influencing distributional patterns of species richness in galling insects. The objective of this work is to analyze how variation in water and nutrient availability, plant species number and plant biomass correlate with species diversity of galling insects along two successional gradients. Successional gradients on the dunes of the Indiana Dunes National Lakeshore, Indiana, and around a bog lake in Mud Lake Nature Preserve, Michigan, offer an ideal environment for ecological studies involving nutrient and water stress, plant species number and plant biomass since some of these factors vary in opposite directions along the two gradients. Indeed, water and nutrient availability, plant species number and plant biomass, vary in the same direction along the successional gradient on sand dunes, with all values being higher at late successional stages. Nutrient availability and plant biomass are also higher at later successional stages around bog lakes. However, water availability increase as distance to the bog lake center decreases and plant species number is higher on the shores of the bog lake than in the climax forest. Nine 20 x 20m plots will be sampled along the two successional gradients in which gall and plant species numbers will be recorded. Soil samples will be collected for water content and nutrient analysis and plant biomass will be estimated.

Research Objectives

Different hypotheses have been proposed to explain variation in abundance and diversity of galling species (Fernandes and Price 1991). Some of the most compelling hypotheses are: 1) the harsh environment hypothesis, which predicts that galling species richness will be higher in dry, hydrothermally stressed, and/or nutrient-poor habitats; 2) the plant species richness hypothesis, which predicts a positive correlation between plant species and galling species number; and 3) the plant biomass hypothesis, which predicts a positive correlation between plant biomass and galling species number.

The objective of this work is to test the hypotheses explaining diversity of galling insects by examining presence of galls along two successional gradients that vary in water and nutrient availability and in plant species number and plant biomass. The two successional gradients selected for study are the sand dunes of the Indiana Dunes National Lakeshore, Indiana, and around a bog lake at Mud Lake Nature Preserve, Michigan. These sites are ideal for ecological

studies involving water and nutrient availability, plant species richness and plant biomass because some of these factors vary in opposite directions along the two gradients.

Background Information

Price and Fernandes (1991) found that temperate galling species distribution is influenced by hydrothermal stress. Galling species richness in general was greater in xeric sites than in mesic sites. Higher species richness in xeric sites may be due to greater risk of parasitism and higher mortality of galls in mesic sites. Indeed, results from studies comparing galler mortality on the same host plant in xeric and mesic sites support the view that gallers survive better in xeric sites. The invasion of the gall by endophytic fungus is a major cause of mortality of several galler species (Carroll and Carroll 1978). Parasites and fungi thus apparently deter gallers from becoming more abundant in mesic sites. This is not surprising since fungal reproduction and growth depend on humidity. Therefore, the differential survivorship in xeric and mesic habitats may be the general proximate factor influencing the distributional patterns of galling species richness. The ultimate factor influencing such distributions would be an evolved response of females, which select xeric instead of mesic sites (Fernandes and Price 1991).

Galling appears to be strongly associated with sclerophylly. The association of galls with sclerophyllous plants had been noted in earlier studies by Fernandes and Price (1988), and may reflect interactions with potential herbivore competitors. Sclerophylly is common in plants growing on soils with low levels of nutrients, particularly low phosphorous (Grubb 1977). Such plants generally have higher concentration of secondary compounds, especially cyanogenic glycosides (Clark et al. 1979), glucosinolates (Gershenson 1984), alkaloids (Bradford and Hsiao 1982), phenolic compounds (Muller et al. 1987), and terpenoids (Gershenson 1984). Gallers, however, are able to circumvent these plant defenses; the gall tissue in which the gall larvae feed is phenol-free (Larew 1982). Consequently, gallers in xeric or nutrient-poor sites may occupy a niche with relatively low levels of parasitism and competition (Fernandes et al. 1987).

In addition, plants growing on nutrient poor-soils tend to develop long-lived leaves (Coley et al. 1985) reducing the probability of abscission and increasing leaf toughness (Grubb 1986). Gallers are more prone to colonize and survive in such long-lived leaves.

Plant species richness may be a predictor of gall-forming insect diversity since gallers are usually host-specific. However, empirical data are equivocal regarding the importance of plant species richness in predicting species richness of galls (Fernandes and Price 1988); general correlations exist, but such correlations do not have any explanatory power.

Finally, gall diversity also may be positively correlated with plant biomass, as leaf area available for colonization by gall species increases with biomass.

Project Description

The successional gradients on the dunes of the Indiana Dunes National Lakeshore, Indiana, and around a bog lake in Mud Lake Nature Preserve, Michigan, offer the appropriate environment to test the harshness, plant species number and plant biomass hypotheses.

Water and nutrient availability vary in the same direction along the successional gradient on sand dunes, being higher in later successional stages (Fig. 1). In such habitats, thick litter layers and shade produced by taller plants keep soil moisture relatively high. Furthermore, pH of the soil decreases with dune age due to the quick leaching of carbonates. Soil nitrogen increases rapidly in the first 1000 years of development, from very low values initially to approximately 0.1%, and then remains unchanged in older dunes. Organic carbon in the soil develops similarly (Olson 1958). Nutrient availability is lower at early successional stages around bog lakes because of the low rate of decomposition. However, water availability follows the opposite direction, decreasing as distance from the lake increases (Fig. 2).

The same relationships occur for plant species richness and plant biomass, as both vary in the same direction along successional gradients on sand dunes, with higher values occurring at later successional stages (Fig. 3). Plant biomass is higher in climax forest than in early successional stages around bog lakes. However, the great diversity of herbs and shrubs growing on the shores of bog lakes may result in higher plant species number in intermediate successional stages (Fig. 4).

This study is designed to investigate how water and nutrient availability, plant species richness and plant biomass (independent variables), as well as gall species number (dependent variable) vary along the two successional gradients. Such information allows the assessment of the influence of the predictor factors on gall diversity in two ecologically different sites. The contrasting directions of the variation in water and nutrient availability, and in plant species richness and plant biomass between the two successional gradients may increase the resolution of these patterns.

Nine 20 x 20m plots will be sampled along the two successional gradients. The gradients will be divided into 3 classes with respect to the stage of succession: early, mid, and late. Three plots will be assigned to each class. Gall and plant species number in the plots will be recorded. Ten soil samples will be collected from each plot for nutrient analysis (N, P, and K). Ten records of soil water availability will be taken per plot by means of a tensiometer. In addition, estimation of plant biomass will be based on combined measures of DBH for trees, height for shrubs and percentage of cover for herbs. Plant biomass data will be divided into classes due to the roughness of the estimation procedure used here.

One-way ANOVA will be used to confirm gradient assumptions. The treatments will be early, mid, and late successional stage and the dependent variables will be soil water availability, nutrient availability, plant species number, and plant biomass. To examine the relationship between gall species number and successional stage two-way ANOVA will be used, in which treatment and site will be the independent variables.

If the working assumptions of this proposal, summarized in Figures 1 to 4, are incorrect, further studies will be required, likely including experimental manipulations in order to determine relative importance of each factor. Indeed, since this work does not involve experimental manipulation, causal relationships can only be inferred from patterns.

Significance of Proposed Research

The basic problem of ecology is to determine the causes of distribution and abundance of organisms (Krebs 1977). The increase of species diversity with decreasing latitude is well established. This pattern of animal distribution and diversity is somewhat mimicked by altitudinal gradients (Holdridge 1967). Nonetheless, many other factors can be important depending on the spatial scale in which the question is focused.

Insect galls are good subjects for ecological studies. Their abundance, diversity, and sessile habit make them easier to census than other herbivores. Besides, insect galls occur in virtually all terrestrial habitats.

This work deals with some ecological variables and their correlation with gall species diversity in a local scale. Its results will contribute to our understanding of the interaction among factors which produce distributional patterns in galling insects. Given the abundance, diversity and wide range of occurrence of galling insects, results of this study will aid in the elaboration of general models to explain patterns of distribution and abundance in local, regional and global scales.

Acknowledgments

I am grateful to XXXXXX for reviewing the manuscript and for constructive comments.

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