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GIS as a Tool for Modeling Ecological Relationships

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GIS as a Tool for Mapping Ecological Relationships

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Abstract

A geographical information system (GIS) is a tool for mapping, presenting, and analyzing spatial data on multiple planes. GIS is often used to create predictive models that can pinpoint locations of certain criteria, but it can also be used to understand the relationships between points on these planes. As ecology is the study of interactions between biotic and abiotic factors, GIS is a valuable instrument for studying the interactions within ecological systems with respect to space, time, and scale. For example, the chemical ecology of ant-homoptera mutualisms was mapped using GIS. Diversity of sugars was found to vary widely between specific locations within the study site using HPLC-RID (High Performance Liquid Chromatography - Refractive Index Detector), suggesting varying types of interactions within the same species. A visual geographic mosaic of coevolution was then generated using GIS. In the future, GIS will be applied to the ecology of vector diseases. A detected sexual dimorphism of the Chagas-carrying triatomine bug will be analyzed in the spatial context of several biotic and abiotic factors. Understanding where this dimorphism does and does not exist will allow for a more comprehensive understanding of this organism’s life history strategy and, therefore, control of the disease. Thus, GIS is a powerful tool for evaluating dynamic and varied relationships within an ecosystem.

Introduction

A geographical information system (GIS) is a tool for mapping, presenting, and analyzing spatial data on multiple planes. GIS is often used to create predictive models that pinpoint locations of certain criteria, but it can also be used to understand the relationships between points on these planes with respect to time, space, and scale.

Ecology is the study of interactions within an ecosystem, but interactions between species are generally categorized as positive, negative, or neutral. In contrast, the geographic mosaic theory of coevolution proposes that interactions vary greatly between populations within a species (Thomspon 1999, Figure 1). Within environments exist both coevolutionary hot spots, where two or more species strongly affect the fitness of each other, and cold spots, where species have little effect on each other's fitness (Gomulkiewicz et al. 2000).

These studies strive to model ecological interactions according this theory using GIS. First, we explore the use of GIS to understand the mutualistic relationship between Argentine ants (*Linepithema humile)* and homopterans (e.g. aphids) in the Ballona Wetlands. Homopterans produce a variety of sugars consumed by ants. In turn, homopterans receive protection from predators.

We then assess how to apply the methods from this study to the ecology of vector diseases, specifically Chagas disease in El Salvador. Triomine bugs carry the protozoan parasite *Trypanosoma cruzi* that cause Chagas disease (Cedillos et al. 1975, Agriculture and Life Sciences at Texas A&M University). A sexual dimorphism was recently detected in populations of this bug in El Salvador, but it is unclear why it exists only in certain populations (Dix, personal communication).

Methods

Ant Collection

Ants were sampled from 17 trees at 14 different sites in the Ballona Wetlands. Each site's GPS coordinates were collected using Terrasync software on Trimble GPS 7x. These coordinates and sugar preferences were then overlaid onto a map of the Ballona Wetlands in QGIS Essen.

Sugar Identification

Ants were crushed, placed in microcentrifuge tubes, and run through HPLC-RID (high performance liquid chromatography – refractive index detector). Sugars were identified by comparing carbohydrate elution times from HPLC-RID to known elution times. Sugars common to each site were then compiled into a network map.

Results

- Ants displayed differential sugar consumption by population.
- Many of the same sugars were available across study sites.
- Sugars differed in quality and carbohydrate content, meaning that ants receive different quality of rewards in exchange for protecting homopterans.

Discussion and Future Work

Argentine-homopteran interactions in the Ballona Wetlands are consistent with the geographic mosaic theory of coevolution. Future studies should assess the sugars received in similar mutualistic relationships, such as those between pollinators and flowers.

GIS will similarly be applied to analyze the sexual dimorphism of triatomine bugs in the spatial context of the populations' habitats. Understanding where, and potentially why, the dimorphism exists will allow for a more comprehensive understanding of the organism's life history strategy and evidence-based strategies to control the spread of Chagas disease (Sasagawa et al. 2014).

Traditional broad categorization of relationships do not capture the diversity of interactions that exist within ecosystems. GIS is a valuable tool to capture this. To this end, it is being increasingly utilized in the fields of ecology and environmental science. Students currently lack access to GIS courses at LMU, but would greatly benefit from being equipped with this tool for their studies.

Figures and Tables

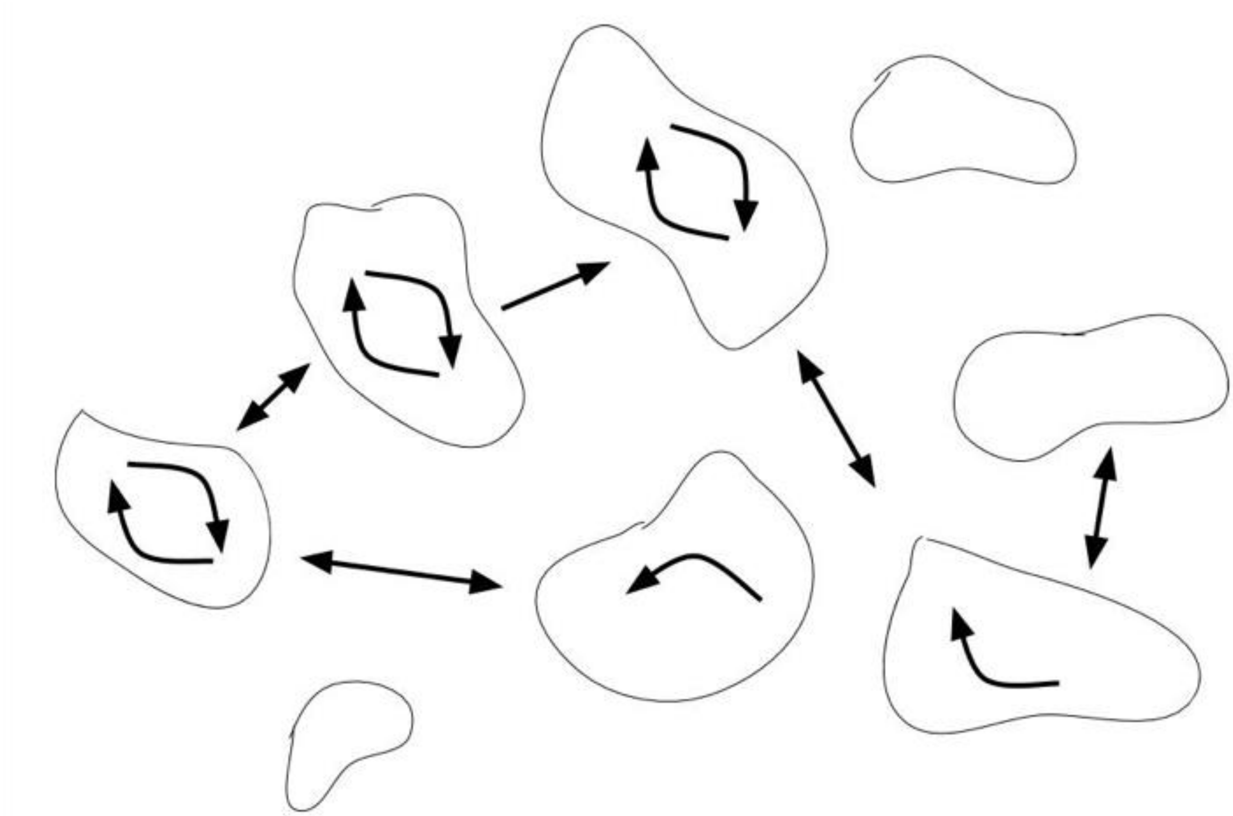

Figure 1. A visual representation of the geographic mosaic theory of coevolution. Shapes represent communities. Arrows within shapes represent interactions between community members. Arrows between shapes represent gene flow.

Figure 2. Differential sugar preferences of each population at each site in the Ballona Wetlands of Los Angeles, California.

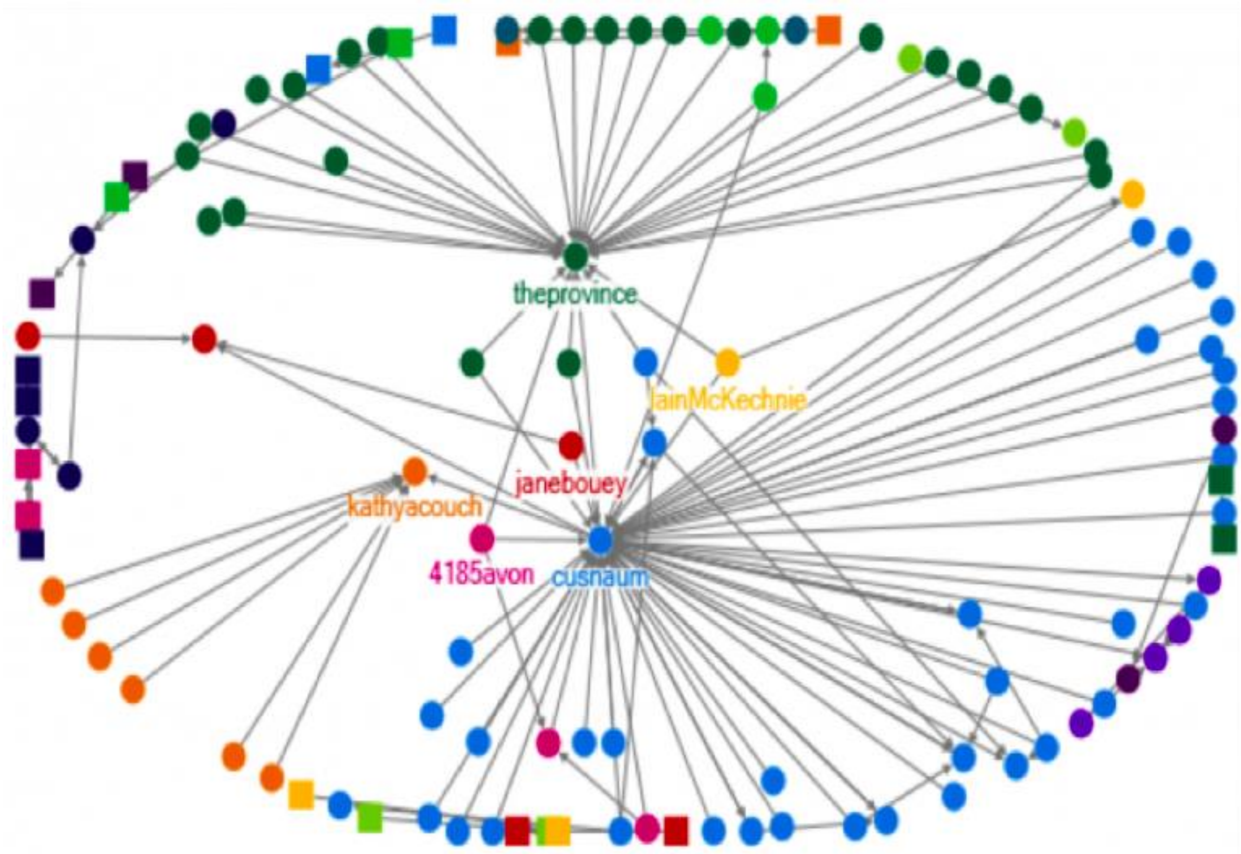

Figure 3. Map of which sugars were common to each study site.

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