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Clustering of ant communities and indicator species analysis using self-organizing maps

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ABSTRACT

To understand the complex relationships that exist between ant assemblages and their habitats, we performed a self-organizing map (SOM) analysis to clarify the interactions among ant diversity, spatial distribution, and land use types in Fukuoka City, Japan. A total of 52 species from 12 study sites with nine land use types were collected from 1998 to 2012. A SOM was used to classify the collected data into three clusters based on the similarities between the ant communities. Consequently, each cluster reflected both the species composition and habitat characteristics in the study area. A detrended correspondence analysis (DCA) corroborated these findings, but removal of unique and duplicate species from the dataset in order to avoid sampling errors had a marked effect on the results; specifically, the clusters produced by DCA before and after the exclusion of specific data points were very different, while the clusters produced by the SOM were consistent. In addition, while the indicator value associated with SOMs clearly illustrated the importance of individual species in each cluster, the DCA scatterplot generated for species was not clear. The results suggested that SOM analysis was better suited for understanding the relationships between ant communities and species and habitat characteristics.

1. Introduction

Ants are considered to be one of the most suitable taxa for assessing ecological integrity in terrestrial ecosystems [1–3]. Ant community characteristics are affected by a variety of environmental factors that act on habitats [4–7]. Furthermore, ants are typically relatively sedentary and are thus sensitive to small-scale spatiotemporal changes in the environment [8]. Ants are therefore efficient indicators of the impact of environmental changes in an integrative and continuous manner.

Although ant community characteristics reflect ecological integrity fairly well, these community data are highly complex and difficult to analyze, primarily because communities consist of numerous species and also because they respond in highly complex manners to natural and anthropogenic pressures in their environments. A variety of ordination analyses have therefore been employed to describe ant communities. Davis and Zigler [9] used detrended correspondence analysis (DCA) to show that ant communities differed significantly between different habitat types and that species composition over time. Sarty et al. [10] clarified the influence of invasion by *Anoplolepis gracilipes* on ant community composition and species abundance using

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non-metric multidimensional scaling (NMDS). Indeed, DCA and NMDS are used extensively for the analysis of community data, but the methods sometimes fail to show clear clustering and habitat preference of species [11,12].

Self-organizing maps (SOMs), which are another method used in ordination analysis to mine nonlinear data, have been used extensively to characterize patterns in communities since the 1990s [13,14]. The SOM method can efficiently classify a bi-dimensional projection of habitat characteristics; for example, SOMs can illustrate the community response to anthropogenic disturbance at a site and clarify how such disturbance affects species occurrence [15–17].

This study aimed to:

- characterize the distributional patterns of ant communities in various habitats;
- compare SOM and DCA ordination methods;
- visualize distribution patterns of ant species;
- quantitatively estimate the relative importance of each ant species in each habitat.

We applied the SOM and DCA methods to characterize ant community structure and distribution patterns according to land use type. In addition, we employed an indicator value (IndVal) to quantify the importance of each species identified using the SOM map. This approach was proposed by Park et al. [18] and has recently been employed to better explain ecological data [19,20].

2. Materials and methods

2.1. Study site

Habitat and ant surveys were carried out at 12 study sites in Fukuoka City, Kyushu, Japan, from 1998 to 2012 (Fig. 1). The 12 study sites were classified into nine land use types, which were grouped into one of two categories: open areas (open urban parks, coastal areas, and agricultural fields) and forested areas (evergreen forests, shrine forests, urban park forests, deciduous forests, bamboo forests, and cedar forests) (Table 1). Each land use type presents ants with a variety of structurally different habitats and biotic factors. In addition, the characteristics of each habitat have been maintained by surrounding environmental conditions and/or continuous management. For instance, the management of open urban parks is directed at preventing the free growth of planted trees, which limits the provision of habitats containing large quantities of decaying nesting material. We resampled two sites (S05 and S06, Table 1) to clarify whether ant communities were influenced by land use type or time.

2.2. Sampling method

We used time-unit sampling (TUS), which is a direct sampling method that is well suited for making a comprehensive inventory of species at different study sites. TUS involves collecting as many species as possible by visually and manually searching for ants on the ground surface, under stones or under wood bark, and around the bases of tree trunks. Although direct sampling methods are effective for capturing the majority of species at a site [25], such methods are not well suited for studies involving quantitative comparisons between sites [26]. TUS is designed to address this weakness by repeatedly sampling sites over a fixed period of time. The tools employed to capture the ants were aspirators, sifters, pans, and vials containing 70% ethanol [27].

The time unit and the number of TUS times were considered based on the conditions at each study site. Of the 12 study sites identified, 2 were sampled 10 times, 6 were sampled 8 times, and 6 were sampled 16 times (Table 1). These 164 samples were used to analyze ant community and occurrence patterns of indigenous ant species according to land use type. In this study, we defined unique and duplicate species as those that were only recorded once or twice among the 164 samples.

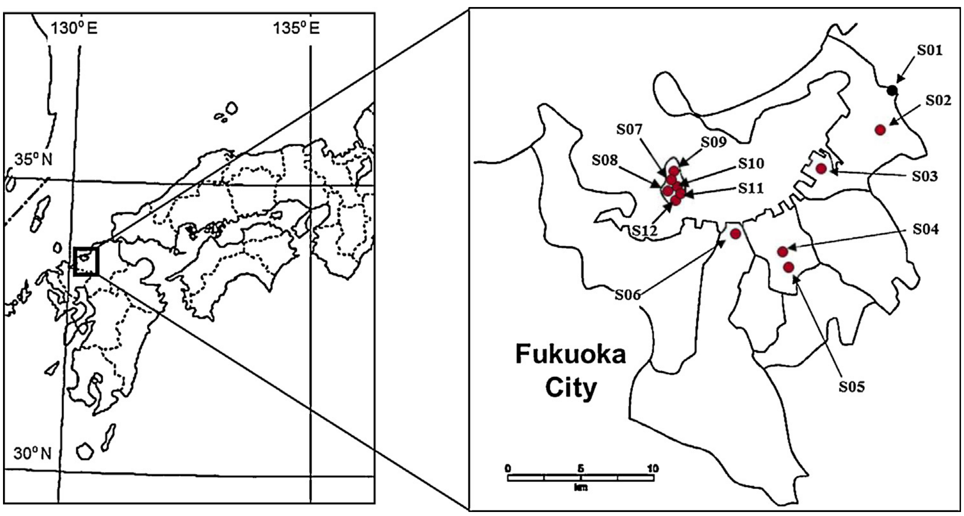

Fig. 1. Map of the location at the 12 study sites in Fukuoka city, Japan.