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Butterfly-plant network in urban landscape: Implication for conservation and urban greening

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ABSTRACT

Butterflies (Insecta: Lepidoptera) contribute to the ecosystem services and thereby qualify as a group deserving conservation effort. Information on the butterfly-plant links is used as a foundation to sustain population and enhance conservation and management. Thus, in the present study, the structure of a butterfly-plant network in an urban landscape like Kolkata, India, was deciphered highlighting metrics like degree distribution, nestedness, and interaction strength and specialization index. A total of forty eight butterfly species associated with thirty different angiosperm plant species were observed during the study period of one year. While *Lantana camara* was observed to be the dominant plant species with 37 links to different butterflies, the *Catopsilia pyranthe* butterfly species was dominant in terms of the generalist pattern of links (21 links) with the plants. Differential ability of the shrubs and herbs in the sustenance of the butterflies was reflected in the network indices using the herbs and the shrubs, separately. In urban landscapes with restricted variety of flowering plants, an estimate of relative strength of interactions enables identification and further use of the concerned species in sustaining butterfly populations. In accordance with these propositions, the butterfly-plant network illustrated in the present instance may prove useful in selection of plant species required for the enhancement of population of desired butterfly species in urban areas like Kolkata, India.

1. Introduction

Insect mediated pollination is a key ecosystem service that facilitates the sexual reproduction of different crops (Nabhan and Buchmann, 1997; Westerkamp and Gottsberger, 2000) and wild plants (Larson and Barrett, 2000; Ashman et al., 2004). As a result, food security and environmental quality are retained, benefiting human well-being (Knight et al., 2005). Among insects, butterfly qualifies as an important pollinator of different plants. Coevolution of many plants and butterflies has resulted in development of specific plant features which in turn encourage the butterflies to utilize the flowers (Edger et al., 2015). Butterflies serve as indicator of the climate change as well as changes associated with natural and anthropogenic disturbances (Vickery, 2008). In many instances, the decline in the butterfly fauna is attributed to a corresponding decline in nectar-rich and economically important wild plant species (Gillespie and Wratten, 2012). The distribution and diversity of the butterflies and plants are pre-requisite for framing the strategies of conservation, particularly for the urban ecosystems. This proposition is based on the previous studies that indicate that urbanization affects biodiversity patterns (Pauchard et al., 2006) including diversity of butterflies (Bergerot et al., 2011). Empirical studies have shown that the small patches of gardens (Fontaine et al., 2016; Tam and Bonebrake, 2016) and forests (Soga and Koike, 2012; Lee et al., 2015) in the urban areas are valued spaces for sustenance of butterflies. However, conservation planning in such habitat patches requires the information on the butterfly and plant species assemblages of the concerned area. In Kolkata, India, the diversity of the butterfly and associated plants has been recorded in the recent past (Mukherjee et al., 2015, 2016). An extension of such study was made in the present instance, where the links between the specific butterfly species and the plant species are highlighted through a network of butterfly-plant interactions.

Ecological network analysis characterizes the interactions among species or guilds and provides complementary information on species organization and community structure (Ings et al., 2009; Fortuna et al., 2010). Analysis of ecological interaction network aid in determining community assemblage and robustness, resource partitioning, and associations among component species (Montoya et al., 2006; Santamaría

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and Rodríguez-Gironés, 2007). Network ecology is useful in framing the conservation strategies (Kaiser-Bunbury and Blüthgen, 2015; Harvey et al., 2017) as it provides a basic architecture to the levels of biodiversity of the groups involved in mutualistic interactions. Using the indices like connectance and links, the network facilitates identification of the degree of specialization among the interacting species. As a consequence, the network may help decipher the architecture and the functional diversity of the species concerned at the proximate level. In the recent past, network analysis has been widely useful to the study of plant–pollinator or plant–insect interactions (Bascompte et al., 2003; Vázquez and Aizen, 2004; Santamaría and Rodríguez-Gironés, 2007; Ramos-Jiliberto et al., 2009; Olesen et al., 2011). Among the various networks, the bipartite network (in ecology mainly interaction networks with two trophic levels) utilizes newer indices (Bersier et al., 2002; Blüthgen et al., 2006) that facilitates portrayal of the relationships among the constituents of the ecological community (Blüthgen et al., 2007, 2008) and the connection between land use/landscape structure, network structure and ecosystem function (Kaiser-Bunbury and Blüthgen, 2015; Harvey et al., 2017).

In the present instance, information on the richness and abundance of butterflies and plants of Kolkata, India, was used to construct a bipartite network. The indices of the network were used to justify the specialist or generalist nature of the butterflies in the context of plant resources utilization pattern. In addition, the nestedness feature of the network would reflect the extent of the generalist butterflies present in the community. Information obtained through the network analysis would be useful in conservation management of butterflies in the long run, since the role of the specific plants as organizer of the butterfly species assemblage can be identified and subsequently used in the enhancement of the butterfly community. In urban ecosystem, the anthropogenic activities decrease the butterfly diversity due to systemic elimination of several nectar rich and economically important wild species (Gillespie and Wratten, 2012). Further, owing to space limitation (Fontaine et al., 2016; Tam and Bonebrake, 2016), conservation effort in urban areas calls for selection of plant species that are preferred by the butterflies. Thus, one of the objectives of the study will include identification of the flowering plants and their relative importance in the sustenance of the butterflies as deduced through the indices of the bipartite network. Apart from indicating the abundance of the generalist species of butterflies, the results are expected to highlight whether the herbs and the shrubs bear differential consequences to the status of butterflies as generalist or specialist. The information will be useful for the conservation and enhancement of the ecosystem services attributable to the butterfly in urban scenario of Kolkata metropolis.

2. Materials and methods

2.1. Sampling site

Three sampling sites were randomly selected from Kolkata Metropolitan Area (KMA), Kolkata, India. The survey was conducted around a central point of selected study sites. The central points were Talapark (22° 36′ 28.9692″ N, 88° 23′ 1.878″ E), Rabindra Sarobar (22° 30′ 44.0028″ N, 88° 21′ 49.482″ E) and Beliaghata (22° 34′ 1.3224″ N, 88° 23′ 34.908″ E), Kolkata.

2.2. Sampling period and time

The nectar feeding butterflies were observed in the sampling sites for a period of one year between September 2012 and August 2013. Each study site was visited once in a month and transects ware observed from early morning (07:00 h) to afternoon (17:00 h) during good weather periods without heavy rain or strong wind.

2.3. Sampling techniques

In each sampling site the butterflies were recorded following ‘Pollard Walk’ method (Pollard, 1977; Pollard and Yates, 1993) with required modifications. For each site, five transect paths were considered, comprising of 1000 m in length with a minimum of 500 m gap between two transects (Mukherjee et al., 2015, 2016). Among the butterflies, those that placed their proboscis within the respective flowers of a plant were taken into consideration only. In instances where the butterfly sat on the flower without any activity, were not counted and excluded from analysis. During each visit, a single plant species was observed for 15 min for recording butterfly species. Observations of butterflies were restricted to only flowering branches of the plants positioned up to 4 m height (Smith-Ramírez et al., 2005). Data on plant habits, flowering period and flower colour were also recorded for the present study. The plants were identified up to their respective families and species using appropriate keys (Kehimkar, 2000; Paria, 2005, 2010).

2.4. Data analysis

The interaction matrix of plant and butterfly was arranged in two ways. The weighted matrix included frequency of interaction of each butterfly species on each plant species and the unweighted or qualitative matrix with data of presence/absence of the butterfly species on plant species. The indices like connectance, generality, vulnerability, nestedness, degree of distribution were used for qualitative analysis (Blüthgen et al., 2008) and the indices namely weighted connectance, links per species, weighted NODF, specialization asymmetry, degree of complementary specialization (H_2’), number of shared partner, interaction strength, interaction evenness were used for weighted matrix (Blüthgen et al., 2008; Dormann et al., 2008, 2009). The connectance, C, was calculated as C = L/IJ, where, L describes the number of realized links, I and J were the number of plant and butterfly species respectively (Jordano, 1987). The connectance was interpreted as the degree of generalization or redundancy in a system, with consequences for community stability (Estrada, 2007). Therefore, in the absence of sampling limitation, the expected connectance was assumed to be, C = 1. The nestedness was calculated by comparing system temperature, T (Atmar and Patterson, 1993) with values ranging from 0° to 100° the level of nestedness, N = N (100 - T)/100, with values ranging from 0 to 1 (maximum nestedness) (Bascompte et al., 2003). The nestedness was calculated using the NESTEDNESS CALCULATOR software and was represented graphically with the plant species and butterfly species were denoted by x-axis and y-axis respectively (Atmar and Patterson, 1993). In addition to the graph, a z-score was used to test the probability levels (using software package NeD (nestedness for dummies) (Strona and Fattorini, 2014)). Usually NODF (nestedness measure based on overlap and decreasing fills) (Almeida-Neto et al., 2008) and matrix temperature were used to measure nestedness (Almeida-Neto et al., 2008; Strona et al., 2014a; b). The degree distribution of each species was calculated on the basis of the number of links per species in the unweighted matrix.

However, the unweighted matrix represented the scenario of plant–animal network in a limited way. In this qualitative approach, interactions between a consumer and a resource species are only scored in a binary way as 'present' or 'absent', ignoring any distinction between strong interactions and weak or occasional ones (Blüthgen et al., 2006). In interaction networks, the quantitative interaction strength (b_{ij}) represents the proportion of interactions involving ith species with a specific partner (jth species) among the total possible interactions. (Jordano, 1987; Bascompte et al., 2006). The weighted matrix was treated as bipartite network and the bipartite graph and all the indices were calculated in the R software (Chambers, 2008) with bipartite package (Dormann et al., 2008, 2009). As, level of community, the degree of complementary species (H_2′) for entire network was