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Original article

Temporal and spatial assemblages of invasive birds occupying the urban landscape and its gradient in a southern city of India

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ABSTRACT

Common birds play an important role in regulating the functioning of urban ecosystems. Typically, a few common species have become invasive species threatening biodiversity worldwide. Our understanding of the dynamics of invasive birds in an Indian context is still in its infancy. Hence, we studied the gradual adaptation of invasive birds to novel habitats and their dispersal dynamics in a southern city of India. We tested the prediction that urban matrix are increasingly composed of invasive generalist species. The results illustrate the dominance of invasive species such as *Corvus splendens, Acridotheres tristis, Acridotheres livia,* and *Milvus migrans* in the urban environment. The significant abundance of *C. splendens* exhibited urbanization-induced homogenization. The land-use pattern showed more inclination toward the urban structures than the vegetative attributes. Specialist groups from the frugivore guild were found to decline from the urban environment, which may shed light on the ecological factors that constrain their distribution.

Introduction

Urban ecosystems may play a vital role in supporting biodiversity; however, these ecosystems are often the prime locations for the spread of invasive species. Invasive species are now recognized as one of the major drivers of global biodiversity loss and they pose a serious threat to biodiversity (Butchart et al 2010). Urbanization-induced environmental changes favor the spread of invasive species, thereby reducing accessible areas for native species (Bigirimana et al 2012; Clavel et al 2011; Duncan et al 2011; Zhang et al 2011). There is growing evidence that large numbers of birds are invading areas beyond their natural geographical distribution due to human activities (Cohen and Carlton 1998; Mack et al 2000). As urbanization increases, habitat fragmentation and invasion of species hasten around urban centers, causing substantial environmental (competition, hybridization, and predation) and economic impacts (agriculture, livestock, forestry, human health) to the regions of their introduction (Pimentel et al 2000). Conversion of urban matrixes often favors birds (Chace and Walsh 2006; Marzluff et al 2001a; Moller 2009) as their environments are characterized by more anthropogenic food resources and favorable climatic conditions (Rebele 1994). Previous studies have shown that bird species that are widespread and abundant in their native regions are more likely to be introduced than narrowly distributed species (Blackburn and Duncan 2001; Cassey et al 2004; Jeschke and Strayer 2006). Studies have also shown that invasive birds belong to a limited range of families, such as Anatidae, Phasianidae, Psittacidae, and Passeridae (Duncan et al 2006; Kark and Sol 2005).

However, which particular species of bird may become invasive is difficult to predict as different habitats and varied climatic conditions may provide invasion for different species of birds. Some of these species establish beyond their native range and spread (Kolar and Lodge 2002), and hence are called “invasive.” Invasive birds are classified based on criteria such as higher population density of breeding birds than nearby rural populations (Moller 2009; Moller et al 2012), species that are able to breed in urban centers (Croci et al 2008), or the difference in population density between urban and rural habitats (Evans et al 2011). Most of the research on invasion biology focuses on quantifying the impact of existing invasions and their distribution rather than analyzing the potential for future invasions and their impact (Kolar and Lodge 2002). Two factors that are frequently used to explain patterns of invasion are the climate or habitat suitability of a species in an urban environment (Hulme 2009; Murray et al 2012). Fewer studies have also highlighted the importance of anthropogenic factors (Roura-

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Pascual et al 2011) such as housing density (Amelie et al 2014) and novel feeding innovations (Moller 2009) as important predecessors for invasion. Most of the literature available in invasion biology considers only a single invasive bird species in a particular geographic region and ignores the presence of co-occurring invaders. Moreover, there is only fragmentary evidence on invasive birds in developing countries (Vila et al 2011), including India. Hence, we studied the gradual adaptation of invasive birds and the co-occurring invaders to novel habitats, their abundance, and their dispersal dynamics in a southern city of India, Tiruchirappalli. This study attempts to bridge the gap between urban avifauna with emphasis on invasive species and the anthropogenic factors that influence the spread of invasive birds. We propose and test the following hypotheses: (1) urbanization-induced homogenization is more prevalent in invasive birds and co-occurring invaders and (2) urbanization-related factors are responsible for homogenization of birds. In addition, the study also predicts that *Corvus splendens* may be the most dominant species occupying the urban matrix.

Materials and methods

Study site

The study was conducted in Tiruchirappalli, a southern most city of India, which is more exposed to urbanization developments being in the center of the Tamil Nadu state with rapid growth of urban population and an attractive tourist destination. It lies between 10°10′ and 11°20′ of the Northern latitude and 78°10′ and 79°0′ of the Eastern longitude. Tiruchirappalli lies on the banks of the river "Cauvery," and has numerous tributaries flowing through the district. Being one of the oldest inhabited cities in Tamil Nadu, its earliest settlements date back to the second millennium BC and the ancient monuments here attract a large number of invasive birds providing favorable nesting sites. The district has an surface area of 4404 km^2 and is the fourth largest district in Tamil Nadu, with a population of 27 million, according to the Union Government of India census, 2011. The city is also the fourth largest urban agglomeration in the state. The district exhibits hot and dry climate with high temperature and low degree of humidity throughout the year, with a short period of rainy season and winter from September to December.

Sampling design

Birds were surveyed at 80 locations within the urban matrix for a period of 24 months. These 80 sampling points were visited on a monthly basis with a total record of 1920 observations. For sufficient coverage of survey sites in terms of bird abundance in the urban matrix, the gradient of urbanization was representative of three zones, namely, *urban*, *suburban*, and *urban fringes* (Figure 1). The urban zone is demarcated with 26 points, suburban with 26 points, and urban fringes with 28 points. The study points were spaced at 500 m and were georeferenced with a Garmin handheld global positioning system (GPS). At each point, bird surveys were conducted using the point count method (Bibby et al 2000) within 25 m radius, for 10 minutes from 06:00 AM to 09:00 AM on a monthly basis to maximize count efficiency. Point counts were recorded on a monthly basis to accommodate the breeding period. In consideration of the interspecific and intraspecific interactions among species in a community, both invasive and native species were surveyed (Blair 2004). At each point count, spatial and temporal variations in the most abundant birds were recorded. Species identification was carried out using binocular and field guides including *Birds of Southern India* (Grimmett and Inskipp 2005), *The Book of Indian Birds* (Ali 2003) and *Birds of the Indian Subcontinent* (Inskipp et al 2000), and all birds detected visually and acoustically were recorded. When counting birds, special care was taken that individuals were counted only once. Bird community composition at the different sampling points was expressed by diversity, richness, and the abundance of each species, and a "species by site"

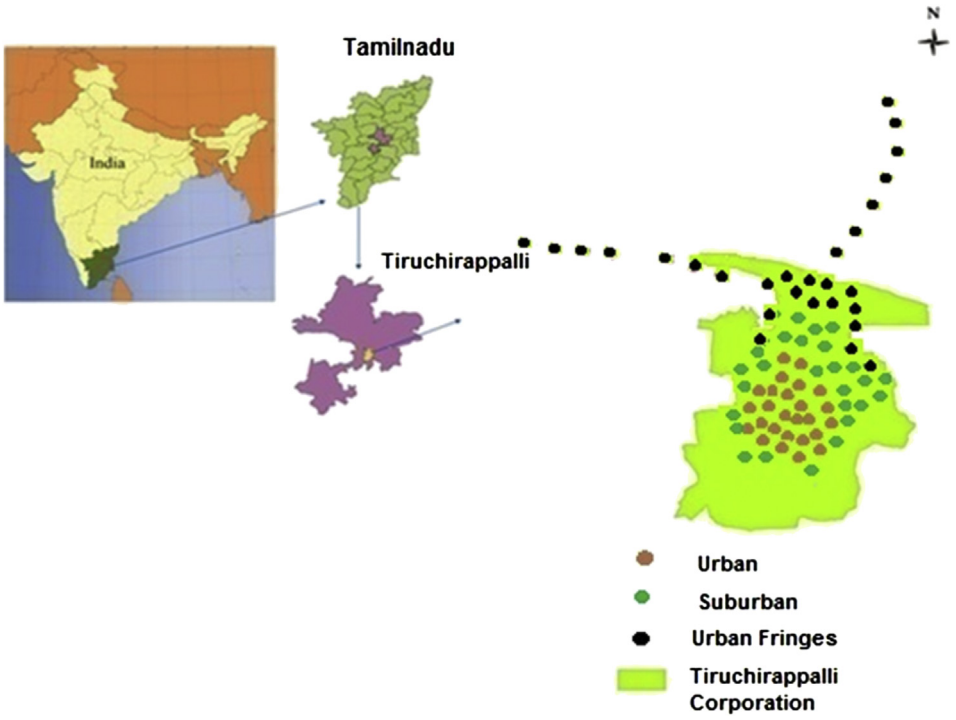

Figure 1. Study area with the sampling locations.