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The response of birds and mixed-species bird flocks to human-modified landscapes in Sri Lanka and southern India

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ABSTRACT

While there is no substitute for undisturbed forest, secondary forests and agroforests are increasingly common in tropical areas and may be critical to conservation plans. We compared the diversity and abundance of birds and the characteristics of mixed-species bird flocks in forests inside protected reserves to "buffer" areas, consisting of degraded forests and non-native timber plantations at reserve boundaries, and to agricultural areas. We monitored a network of 57 transects placed over an altitudinal gradient (90–2180 masl) in Sri Lanka and southern India, collecting 398 complete flock observations and 35,686 observations of birds inside and outside of flocks over two years. Flocks were rarely found in agricultural areas. However, the density of flocks in buffer areas was similar to that in forests, although buffer flocks were smaller in average flock size and differed significantly in composition, as measured by the proportion of species that were classified, from the literature, as forest interior or open-landscape species. While flock composition was distinct between agricultural, buffer and forest areas, the differences in the composition of flocks was not as great as the differences between the overall communities in these different habitats. Considering buffer transects alone, pine plantations retained fewer forest interior species in flocks than did forests, and small areas of agriculture and abandoned agriculture attracted open-landscape species. Though clearly not equivalent to protected forests, degraded forests and agroforests in buffer areas still hold some conservation value, with forest species found particularly in mixed-species flocks in these human-modified habitats.

1. Introduction

Biodiversity loss is a global problem (Butchart et al., 2010), particularly in the tropics where biodiversity is highest. While relatively undisturbed forests are essential for conservation (Gibson et al., 2011), they are not sufficient given that protected areas cover less than 10% of the world's forests globally (Schmitt et al., 2009). The study of how animals live and reproduce in landscapes of human-modified ecosystems, including agricultural areas (Daily et al., 2001), agroforests (Bhagwat et al., 2008) and secondary forests (Chazdon et al., 2009), is thus essential to conservation (Gardner et al., 2009).

Birds are useful taxa to study for understanding the response of animals to anthropogenic disturbance because, besides being predominantly diurnal and readily identified, they are quite sensitive to disturbance, especially for highly mobile animals (Chazdon et al., 2009; Gibson et al., 2011). Birds also extensively interact with other taxa, providing important ecosystem benefits, such as insect control, seed dispersal and pollination (Sekercioglu, 2006). Besides studying the total bird community, it is useful to investigate mixed-species flocks of birds, which incorporate a large proportion of the avifauna in the tropics (Powell, 1985; Greenberg, 2000). Birds that participate in such flocks have been reported to be more vulnerable to anthropogenic disturbance (Stouffer and Bierregaard, 1995; Van Houtan et al., 2006).

Here we investigate how mixed-species flocks, and the total bird community, respond to different land-use types in Sri Lanka and the Western Ghats. Sri Lanka and the Western Ghats represent one of the earth's biodiversity hotspots (Myers et al., 2000; Gunawardene et al., 2007), and of all the hotspots, have the most dense human population (Cincotta et al., 2000). Although mixed-species bird flocks have been extensively studied in the region (Goodale et al., 2009), most of these studies were inside protected reserves, and did not quantitatively relate flock characteristics to land-use. In the present study, we sampled birds inside and outside

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of flocks in three '***broad***' land-use types: inside protected forests, in buffer areas containing degraded forest or tree plantations, and in agricultural areas. Transects were also mapped as to the '***specific***' land-use types (e.g., *Eucalyptus* plantation) found nearby them. Here we report how flock characteristics such as density, size and composition (by which we specifically mean the proportion of forest interior and open-landscape species) were affected by (1) the broad land-uses (the comparison between forest, buffer, and agriculture) and (2) the specific types of land-use, focusing on those found on buffer transects. Further, we look at the response of the overall bird community to these same types of land-uses, in terms of species richness, bird abundance and composition, to trace the implications of differing types of land-use for tropical bird conservation in countryside landscapes.

2. Materials and methods

2.1. Study area

We worked in areas of moist evergreen forest in Sri Lanka and southern India (Fig. 1). The reserves that we sampled in these areas have either not been systematically logged during the last half century (although roads may have been cut through them, $n = 15$ transects), or were selectively logged during the 1970s ($n = 4$ transects) and 1980s ($n = 2$); they are currently relatively well protected, although some small-scale extraction (e.g., polewood and firewood) occurs in some areas. Forests are largely confined to protected areas, but fragments do exist in areas of intensive agriculture (Anand et al., 2010). The Forest Departments of the respective countries, and to a lesser extent private agencies, have planted land bordering forests with timber crops, including *Eucalyptus* sp. in montane Sri Lanka and mid-elevation India, *Pinus caribaea* in lowland and mid-elevation Sri Lanka, and *Tectona grandis* and *Swietenia* sp. in lowland India.

2.2. Sampling

Between December 2006 and December 2007, we sampled three sites in Sri Lanka: the Sinharaja World Heritage Reserve, western sector (300–500 masl), Sinharaja eastern sector (900–1100 m), and the Nuwara Eliya region (1800–2000 m). For each site, we laid down eight 2-km transects: three transects were placed in relatively undisturbed forest inside protected reserves, three transects in "buffer zones" near the borders of protected reserves, and two transects in areas of intensive agriculture (Fig. 1, sites A–C). Between April 2007 and June 2008, we sampled two sites in southern India: the Thattekad Reserve in Kerala (40–80 m) and the Anamalai Hills in Tamil Nadu (850–1000 m). At each site, we laid down eight 2-km transects following the same methodology as in Sri Lanka (Fig. 1, sites D and E). Finally, between January 2008 and January 2009, we sampled the altitudinal gradient from the Gillimalle Forest Reserve (90 m) to the Horton Plains Reserve (2180 m) in Sri Lanka. Seventeen 1-km transects were placed over this gradient, again attempting to match transects of one type of land-use with nearby transects of the other types, although for logistical reasons such matching was not perfect (Fig. 1, these transects are between the A, B and C sites).

For transects we chose pre-existing paths or small roads that were relatively straight, and ensured that transects were at least 250 m away from each other at all points. Detailed maps were constructed for the area 25 m to each side of each transect, classifying the specific land-use type that was the majority of that area

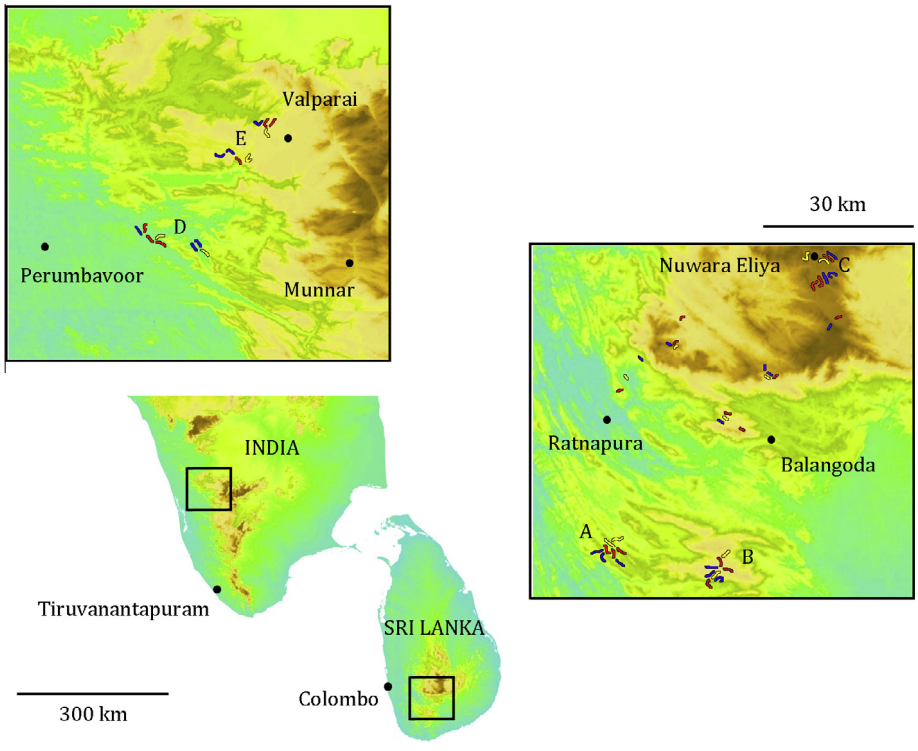

Fig. 1. Transects ($n = 57$) from which observations were made in Sri Lanka and India over an altitudinal gradient. Transects through forests are blue, those in "buffer" lands (degraded forests or plantations) at the border of forests are red, and those in agricultural lands are yellow. Beige colored areas are between 1000 and 1500 masl, with dark brown above that and green and blue below. The width of the transect is not to scale. Topographical data are void-filled seamless SRTM data V1, 2004, from International Center for Tropical Agriculture (CIAT), available from the CGIAR-CSI SRTM 90 m database at_http://srtm.csi.cgiar.org. (A) Western sector of the Sinharaja World Heritage Reserve; (B) eastern sector of Sinharaja; (C) Nuwara Eliya region; (D) Thattekad Reserve; and (E) Anamalai Hills.

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