Journal of Asia-Pacific Biodiversity 7 (2014) 367–373

Contents lists available at ScienceDirect

Journal of Asia-Pacific Biodiversity

journal homepage: http://www.elsevier.com/locate/japb

Original article

The impact of forest conversion on bird communities in the northern flank of the Knuckles Mountain Forest Range, Sri Lanka

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ARTICLE INFO

Article history:
Received 27 June 2014
Received in revised form
24 July 2014
Accepted 24 July 2014
Available online 4 August 2014

Keywords:
bird species richness
canopy cover
cardamom
pinus
point count method
vegetation structure

ABSTRACT

Initiating proper conservation and management strategies requires assessing the consequences of forest conversion into human land use systems on tropical biodiversity. This study characterized bird species diversity and composition and vegetation structural components in four land use types in the northern flank of the Knuckles Mountain Forest Range, which is a part of a world heritage site in Sri Lanka: an undisturbed forest and three human-modified land uses for cardamom, pinus, and abandoned tea plantations. Using the fixed radius point count method, 1,023 individuals belonging to 51 bird species were recorded. The cardamom plantation with native shade trees had a bird species richness and composition comparable to an undisturbed forest (one-way analysis of variance; $p > 0.05$, Jaccard index = 0.56). Based on the Shannon–Wiener index, the overall species diversity was highest in the undisturbed forest. Pearson's correlation coefficient suggested a strong positive linear relationship between bird species richness with canopy cover ($r = 0.738$) and vertical stratification ($r = 0.813$). Land use systems formed by considerable alterations to vegetation structure significantly reduce bird diversity and supports a bird community that is less comparable to an undisturbed forest.

Introduction

Most natural forests throughout the world have been destroyed and converted to human land uses to meet the ever growing demands for resources (FAO, 2012). Most remaining forest landscapes consequently have a mosaic of human-modified land areas such as urban, agricultural, and plantation lands. The conditions of these land areas have been highly deviated from their previous undisturbed state.

The rate of the loss of forest cover has slowed, compared to the period of 1990–2000 (FAO, 2011); however, it continues to occur at an alarming rate [between 2000 and 2010, the net annual loss of the world's forests was 6.4 million hectares (ha)] and needs a concerted effort to slow or reverse the trend. Most tropical forests that contain a large amount of the world's biological diversity are still being cleared for agricultural purposes and for the timber industry. To date, forest plantations have been established all around the world to compensate for forest loss through agricultural and other anthropogenic disturbances that have become a major contributor to local and global economies. However, most of these plantations that have been established using tree species with fast growth rates greatly differ from the naturally regenerated forests in composition and in structure, which leads to different ecological processes and different functional outcomes (Davis et al., 2012).

It is clearly evident that the conversion of natural forests into human land uses negatively affects the rich biodiversity associated with forest ecosystems (Holloway, 1996; Houlahan and Findlay, 2011; Lupatini et al., 2012; Meijer et al., 2011; Pekin and Pijanowski, 2012; Pimm et al., 2006). This trend is likely to continue with the rapid growth of population that results in increasing demands for forest resources. According to Birdlife International (2013), two-thirds of bird species are found in forests and many of them are restricted to forest ecosystems. Forest conversion is a factor that poses a major threat to the substantial number of bird species. It can destroy and degrade the habitats of species *via* reducing available food sources and roosting and nesting places and *via* restricting movement. However, not all bird species are equally vulnerable to forest conversions (Sekercioglu et al., 2002; Sodhi et al., 2004). Rare and restricted range birds, rainforest habitat specialists, and altitudinal migrant birds are more

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Peer review under responsibility of National Science Museum of Korea (NSMK) and Korea National Arboretum (KNA).

http://dx.doi.org/10.1016/j.japb.2014.07.004

susceptible to habitat alterations, compared to generalists (Raman, 2001). Several studies have shown that some human land uses hold a considerable biological diversity. Agroforestry systems such as plantations of shade coffee (*Coffea arabica*) and cacao (*Theobroma cacao*) support a greater number of forest birds species with a higher diversity, compared to open agricultural systems with few or no trees (Estrada et al., 1997; Greenberg et al., 1997; Petit et al., 1999). This has lead to the question of how vital is it to incorporate human land uses in conservation planning.

The Knuckles Mountain Forest Range (KMFR) in Sri Lanka, which has been declared as a world heritage site because of its rich biodiversity (UNESCO, 2012), has been severely impacted by economic trends over the past several decades. In the middle of last century, some parts of the forest within the range had been cleared to cultivate coffee and subsequently to grow tea (Gunawardane, 2003). Because the climatic condition in this forest range is favorable for cardamom plantation, several planters also engage in underplanting cardamom by removing one-quarter of the overstory of the natural forest (Abeygunawardena and Vincent, 1993). In 1960, this underplanting had become a greater threat to the forest range when the government authorized individuals and groups to grow cardamom. With the initiation of new reforestation policies in the 1960s, several pinus plantations were established around the range (Medawatte et al., 2008). Several attempts have been made to analyze the differences in ecological functions and diversity in these human land uses and undisturbed forest (Dharmaparakrama, 2006; Nizam, 2011; Weerakoon et al., 2010).

The present study reports on bird communities in four land uses in the northern flank of the KMFR: (1) an undisturbed submontane forest (i.e., a type of forest formation common to the selected altitudinal range); (2) a cardamom plantation; (3) an abandoned tea plantation; and (4) an exotic pinus plantation. The differences in bird community structures were assessed in terms of bird species richness, species diversity, and species similarity. This study also investigates the structural components of vegetation in all selected land uses to examine the influence of each component to the species richness of birds.

Materials and methods

Study area

This study was conducted in the northern region of the KMFR. The study area was restricted to an elevation range of 600 m to 1300 m above sea level, which is the range specific to submontane forest vegetation (Bambaradeniya and Ekanayake, 2003). The study area consists of continuous and fragmented submontane forest, commercial plantations of pinus and cardamom, an abandoned tea plantation, and small patches of eucalyptus plantations. This study focused on the prominent human land use types within the study area: (1) cardamom plantations, (2) pinus plantations, (3) abandoned tea plantations, and (4) the submontane forest as an unmodified land use. Figure 1 shows a map of study location.

Bird sampling

Bird sampling was performed from March 2012 to September 2012. A standard fixed-radius point count method (Ralph et al., 1995) with the radius set at 25 m was used to sample birds in all modified land uses and in the undisturbed submontane forest. Sampling was performed for 3 days consecutively in the months of March, April, June, and September. In each visit, a similar number of point count stations were sampled from each land use type. Twenty-eight point count stations were established within each of the four land uses. All stations were established at a distance of 100 m from each other and 100 m from the edge of each land use. The sampling stations were visited between 0600 and 0930 in the morning and 1530 and 1700 in the evening. Each station was surveyed for 10 minutes and all birds detected visually were recorded to the species level, based on the guides by Harrison (1999) and Kotagama and Ratnavira (2010). Detected but doubtful bird species, and uncommon or rare bird species were marked; their identification was subsequently confirmed by acoustical and visual recordings. Any flying birds that were not observed taking off from the point count station were excluded from analysis. No surveys were performed on rainy or windy days. Bird counting was not repeated on any of the point count stations (Ralph et al., 1995).

Vegetation sampling

To describe the vegetation structure of the submontane forest and the human land uses, eight 10 × 10 m subplots were established in eight randomly selected point count stations in each plantation type and forest. Vegetation variables were estimated in each subplot and then averaged for each land use type. In each subplot, every tree with a diameter greater than 10 cm at breast height was counted for the tree density. Tree height was visually estimated within each subplot. A digital rangefinder was used to improve the estimates of tree height (Van Bael et al., 2007).

Vertical stratification (i.e., distribution of foliage at different vertical levels) was assessed at 16 points by recording the presence of foliage at various height classes (e.g., 0–1 m, 1–2 m, 2–4 m, 4–8 m, 8–16 m, 16–24 m, 24–32 m, and more than 32 m) in an imaginary vertical cylinder of 0.5 m radius around the observer (Sidhu et al., 2010). This was measured using two transects established along the center of the point count station with an interval of 5 m. The canopy cover was assessed using a sighting tube with a single central cross-wire (Ganey and Block, 1994; Goodenough and Goodenough, 2012). At each 2-m point along the same transects, the observer looked directly overhead through the tube and recorded whether the crosshair intercepted overhead foliage (Ganey and Block, 1994). The result of each individual measurement was recorded as “1” if the crosshair intercepted foliage and as “0” otherwise. The canopy cover was then estimated as the percentage of points intercepted. The percentage of herbaceous cover (i.e., nonwoody vegetation with a height of less than 1 m) was measured using the point quadrat method (Sutherland, 2006).

Data analysis

One-way analysis of variance, followed by the Tukey test, was used to compare species richness and relative abundance (i.e., the number of individuals per point count station) among undisturbed forest and human-modified land uses after testing the normality of data sets by using the Anderson–Darling test. Statistical analysis was conducted using Minitab 14 statistical software (Minitab Inc., State College, PA). The Shannon–Wiener diversity index (H’) was used to characterize bird species diversity in all land uses. The Jaccard coefficient (Cj) was used to study the similarities of bird species composition between human-modified land uses and the undisturbed submontane forest (Magurran, 2004).

The average number of strata with foliage across 16 points within each point count station was obtained to estimate vertical stratification. Pearson correlation was performed to evaluate the relationship between bird species richness and each of the vegetation variable assessed; for this calculation, only bird community data obtained from the eight point count stations that were selected to determine vegetation structural attributes were considered.