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Original article

Avian frugivory and seed dispersal of a large fruited tree in an Indian moist deciduous forest

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ABSTRACT

Seed dispersal systems in degraded areas can be compromised following the decline of large-bodied frugivore populations responsible for their dispersal. In this context we examined the seed dispersal ecology of a large fruited deciduous tree (*Dillenia pentagyna*) along a forest degradation gradient in India. We examined the effect of structural components of vegetation and frugivore foraging behavior on *D. pentagyna* seed dispersal. Depauperate mammalian community and declined large avian frugivores e.g. hornbills in our study site make this system a specialized one and currently dependent on only two large bodied avian frugivores. Seed dispersal followed an overall leptokurtic pattern and the seed dispersal kernels were best explained by an inverse power function. Seed dispersal kernels in dense forest indicated longer dispersal distances than moderately dense forest and degraded forest. In degraded areas, no dispersal away from the crown was recorded for *D. pentagyna* and it occurred at low density. Canopy foliage abundance of the surrounding vegetation of the focal trees was best explained by quantity of seed dispersal by large avian frugivores. The number of avian frugivore species those are effective disperser of *D. pentagyna* decreased along the degradation gradient. Avian frugivore behavior in terms of visitation and seed swallowed is a determining factor that controls quantity of seed dispersal. Our study underscores deleterious impact of forest degradation on avian disperser community which in turn would affect regeneration capacity of degraded forest.

1. Introduction

Large numbers of tree species depend on the seed dispersal service provided by vertebrate frugivores (Howe and Smallwood, 1982; Strauss and Irwin, 2004). Seed dispersal distance significantly influences the survival of seedlings (Janzen, 1970; Connell, 1971; Spiegel and Nathan, 2007), while long distance seed dispersal ensures maintenance of plant meta-populations in fragmented landscapes and also facilitation of plant migration (Cain et al., 2000; Corlett, 2009). Anthropogenic pressure has led to increased fragmentation of habitats with deleterious effects on the biodiversity (Tscharntke et al., 2008; Stefan et al., 2008). Forest fragmentation also has deleterious impact on vertebrate frugivore populations (Owiunji and Plumptre, 1998; Borges and Stouffer, 1999; Estades and Temple, 1999; Lindenmayer et al., 2002). This will further affect key ecosystem processes like seed dispersal and thereby adversely impact the survival and maintenance of the associated trees in a habitat (Bleher and Böhning-Gaese, 2001; Moran et al., 2004).

Foraging, handling and perching behavior of avian frugivores are also important for the number of seeds dispersed (quantity), seed handling and deposition in sites good for survival (quality) and directional distribution of seeds in a given landscape and consequently influence forest regeneration (Schupp, 1993; Wenny and Levey, 1998). Ensuring the survival of dispersers and understanding their behavior would be better for effective regeneration in degraded habitats (Martínez-Garza and González-Montagut, 1999; Tabarelli and Peres, 2002). Avian communities vary distinctly in different habitats (Walter et al., 2004) and are expected to vary along forest degradation gradient with varied tree species and foliage height diversity (Macarthur and Macarthur, 1961; Macarthur et al., 1966; Karr, 1968; Karr and Roth, 1971; Erdelen, 1984; Schwab et al., 2006). This variation in the frugivores' abundance and diversity in turn is expected to directly affect the seed shadow and seed dispersal pattern of certain trees (Jordano and Schupp, 2000). In this context, assessment of landscape level interactions between trees and frugivores, particularly along gradients of forest

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degradation would be crucial to our understanding about how the degree of landscape modification affects avian frugivore mediated seed dispersal and management of degraded habitats. Unfortunately, knowledge on the status and specific roles of avian frugivores in determining the structure and organization of degraded forest habitats is rather limited (Clark et al., 2005; Gomes et al., 2008).

Trees with large fruits require specialized dispersal system and in some cases large avian frugivores can be instrumental in facilitating long distance seed dispersal of large fruited trees (Howe, 1993). Large avian frugivores often decline in disturbed habitats affecting dependent interactions like seed dispersal therefore measuring loss of ecosystem services along gradient of degraded habitat, particularly forested habitats has become a serious conservation concern (Martínez-Garza and González-Montagut, 1999). A few recent studies have thrown light on how seed dispersal distance changes in heterogeneous landscape and explored how vegetation structure (Herrera et al., 2011) or frugivore behavior (Breitbach et al., 2010) might shape seed dispersal process. However, no study has ever focused on the combined effect of vegetation and frugivore foraging behavior on seed dispersal and this understanding is crucial for creating and managing connectivity in fragmented and degraded landscapes (Carlo et al., 2013). A more complete picture of the interrelationship between seed dispersal efficiency of the frugivores and shapes of seed shadows may be obtained by investigating seed shadow patterns along with behavioral assessments (Wenny and Levey, 1998; Karubian and Duraes, 2009) of the frugivore community.

The present study was conducted in a moist deciduous forest degradation gradient in India in order to understand the role of frugivores in shaping the seed shadow of a large fruited tree. In this forest although most of the deciduous trees are wind dispersed, a few tree species predominantly depend on vertebrate disperser's for dispersal. We conducted our study on a large fruited deciduous tree (*Dillenia pentagyna*) which was earlier reported as both bird and mammal dispersed species (Datta and Rawat, 2008). To understand the seed dispersal ecology of *D. pentagyna* along forest degradation we addressed the following questions: (1) Does the local seed rain and slope of the seed dispersal curve of *D. Pentagyna* vary along the forest degradation gradient? (2) What are the key structural components of vegetation that affect seed dispersal away from the parent plant? (3) Does the frugivore assemblage on fruiting *D. pentagyna* vary along the forest degradation gradient and how does bird foraging behavior influence quantity of seed dispersal.

2. Materials and methods

2.1. The study area

This study was conducted in Kuldiha Wildlife Sanctuary, Orissa, India between May (Summer), 2011 and July (Monsoon), 2012. Located in the southern part of Balasore district of Orissa (21° 20′ 31″ to 21° 29′ 08″ N latitude and 86° 25′ 23″ to 86° 44′ 50″ E), the forest extends over 272.6 km^2. Sakhuapada and Nato hill ranges connect the sanctuary with Similipal Biosphere Reserve (SBR) of Mayurbhanj district. The climate is generally wet and humid with average annual precipitation of 1568 mm. Average elevation of the forest terrain ranges from 101 m to 275 m and is covered with moist deciduous forest. The forest is a mosaic of habitats e.g. evergreen patches, mix deciduous patches, deciduous patches, *Shorea robusta* monoculture and degraded areas and representing various degrees of anthropogenic degradation (Pattanaik and Reddy, 2008; Pattanaik et al., 2010) e.g. selection felling in the past and grazing. Mosaics of agricultural fields, scrublands and degraded forests constituted degraded areas. We further categorized all the patches on the basis of vertical foliage complexity and tree density and classified under three broad category e.g. Dense forest patches, Moderately dense forest patches and Degraded forest patches and they act as three different degradation node along the gradient. Dense forests (dense forest patches) were situated in the core area of the park and had no anthropogenic disturbances. Moderately dense forests (moderately dense forest patches) and degraded forests (degraded forest patches) had medium and high anthropogenic disturbances in term of low and high cattle grazing and selection felling in the past. A total of 23 avian frugivore species was reported from our study area ranging from small to large bodied avian frugivores with differential dietary preferences (Chatterjee and Basu, 2014). Different other vertebrate frugivores are also reported from our study area but most of them are rare (Das et al., 2010).

2.1.1. Focal species

Mature forest trees were rare in degraded forests and *D. pentagyna*, a large fruited deciduous tree that was available along the entire degradation gradient was hence chosen as the focal species. This species produces amongst the largest fruits in the study area (fruit greater than 15 mm was considered as large fruit, David et al., 2015). Flowering of this tree starts in March and ripe fruits are available from May to June (Personal Observation). Fruits are globose in shape, pseudocarp is indehiscent and seeds are exarillate. During fruiting the trees shed all leaves. Fruits are large in size, length = 17.94 mm ± 0.20, width = 17.90 mm ± 0.14, (mean ± SE, n = 60) and mean seed number is 5.25 ± 0.21 (mean ± SE, n = 70) and those are smaller in size, length = 4.55 mm ± 0.05, Width = 3.55 mm ± 0.03 (mean ± SE, n = 80). Edible portions of the fruit include the pseudocarp and seed embedded inner pulp. Average tree height is 12.57 m ± 2.77 (mean ± SE, n = 20). We chose trees under a wide variety of degradation intensification ranging from high foliage complexity and tree density in dense forests to sparse foliage complexity and tree density in degraded forests. We selected five trees each from dense and moderately dense forest patches and four trees in degraded forest patches. Of these 14 trees, three trees each were selected from both dense and moderately dense forest and two trees were selected from degraded forest in 2011. In 2012, again two trees were selected each from all the three habitats. Therefore in the first year, there were a total of eight trees from the three habitats and in the second year there were six additional trees from the three habitats. Average paired distance between respective focal trees were 5.1 km ± 1.5 (mean ± SD).

2.2. Seed trap placement and monitoring

The 14 focal trees were selected for placement of seed traps. To avoid overlapping of seed shadows we ensured that no other *D. pentagyna* tree was fruiting within 250 m from the focal tree (Laman, 1996). And we also ensured that no canopy trees were fruiting at the same radius to reduce the effect of fruit availability on dispersal kernels (Herrera et al., 2011).

Seed traps were prepared with fine plastic mesh (aperture of 2.5 mm diameter) stapled to round bamboo frame of 1 m diameter (area 0.78 m^2). Seed traps were placed after most of the fruits ripened. Traps were hung from surrounding trees at a height of 2 m from the ground to prevent seed removal from traps (Laman, 1996; Clark and Poulsen, 2001; Clark et al., 2005). Two sets of six seed traps were placed each under the tree crown and 7 m from the tree crown. Another three sets of 12 traps were placed each at 7 m, 15 m and 30 m distance from the parent crown. And a total of 18 seed traps were placed at 60 m distance from the parent crown (Fig. 1). Scheme of seed trap placement is after Laman (1996). A total of 54 seed traps were installed under and around single focal tree and a grand total of 756 traps were placed along degradation gradient. All