Forest Ecology and Management 394 (2017) 20–26

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

# Remnant trees and surrounding vegetation determine avian frugivore visitation of restored forest sites in Taiwan

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ARTICLE INFO

*Article history:*
Received 9 November 2016
Received in revised form 18 March 2017
Accepted 24 March 2017
Available online 4 April 2017

*Keywords:*
Applied nucleation
Forest restoration
Frugivorous birds
Landscape context
Natural regeneration
Residual vegetation

ABSTRACT

Natural recovery is an important approach used in forest restoration in many parts of the world. The visitation of avian frugivores, a major source of seed rain in restored sites, is mainly controlled by bird assemblages in surrounding areas and their tendency to enter the restored sites. In this study, we examined the effects of remnant trees, surrounding vegetation, and seasons on avian frugivore visitation in 30 restored sampling plots and 15 edge sampling plots in subtropical Taiwan from 2013 to 2014. The results showed that both remnant trees and the surrounding vegetation were important in avian frugivore visitation of restored sites. Avian frugivores had a higher tendency to enter restored sites with diverse remnant trees and during the non-breeding season. An average of approximately 25% of the avian frugivore individuals in edge sampling plots entered the nearby restored sites within 15 min. Among three surrounding vegetation types, native forests had more frugivores than did conifer plantations. However, if the remnant trees had low species diversity, restored sites surrounded by native forests would have low frugivore visitation similar to restored sites surrounded by conifer plantations. We conclude that the species diversity of remnant trees is more important than the complexity of the surrounding vegetation in increasing avian frugivore visitation. Therefore, in order to promote increased seed rain at restored sites, it is important to maintain the species diversity of remnant trees. For restored sites with limited remnant trees or surrounded by conifer plantations, frugivore visitation would be low, and human intervention might be needed.



## 1. Introduction

Forest plays a vital role in protecting water and soil, storing carbon, and conserving biodiversity (Malhi et al., 2002). However, large areas of forests (especially in the tropics) have vanished during the last decade (FAO, 2010). In addition to protecting remaining forests, conservation efforts are increasingly focused on the restoration of degraded lands (Holl and Aide, 2011). Forest restoration can be passive, through natural recovery, or active, through measures of human intervention. With limited budgets for conservation, natural recovery is an important option for forest restoration in many parts of the world. However, seed sources are often the most limiting factor for natural recovery in degraded lands (Holl et al., 2000). Wind-dispersed species often dominate in degraded lands, and many zoochorous tree species are absent (Nepstad et al., 1996; Zimmerman et al., 2000).

Avian frugivores serve as important seed dispersal agents in forest ecosystems, and nearly 90% of the plant species in a forest ecosystem in Australia were found to be dispersed by avian frugivores (Keenan et al., 1997). Visitation by avian frugivores has been found to be positively correlated with the seed rain of trees and is a critical driver of natural recovery in many areas (e.g., Wunderle, 1997; Holl, 1998; Pejchar et al., 2008). Avian frugivore visitation of restored sites is jointly determined by their presence in nearby areas and their tendency to enter restored sites. Avian frugivore assemblages in nearby area are mostly affected by the vegetation structure. Vegetation types with complex vegetation structure often host more frugivorous individuals and species (Gillespie and Walter, 2001; Ding et al., 2008). Native forests, either primary or secondary, are usually more complex in vegetation structure than plantations or farmlands. Therefore, more visits by avian frugivores are expected to occur in restored sites surrounded by native forests (Lindenmayer et al., 2010; Grainger et al., 2011). However, previous studies have only focused on tree coverage in the surrounding landscape (Crk et al., 2009; Cole et al., 2010; Reid et al., 2014), and the effect of different surrounding vegetation types on frugivore visitation therefore remains unclear.

Forest birds are often reluctant to enter restored sites, where they might experience higher predation risks and fewer food

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http://dx.doi.org/10.1016/j.foreco.2017.03.023
0378-1127/

resources (da Silva et al., 1996). Trees in degraded lands could reduce this avoidance effect by providing shelter in foliage and food resources. Remnant trees are trees that are naturally or artificially retained in degraded lands and could attract birds to these areas (Schlawin and Zahawi, 2008). It has been suggested that remnant trees can nucleate forest recovery by increasing avian frugivore visitation and ameliorating many conditions that limit seedling development (Guevara et al., 1992; Parrotta et al., 1997; Blackham et al., 2013). More frugivores have been found in restored sites with high coverage of remnant trees and more food resources (such as fruits and epiphytes) (Lasky and Keitt, 2012; Sheldon and Nadkarni, 2013). However, previous studies have only evaluated the numbers of avian frugivores in restored sites. To the best of our knowledge, no study has directly examined the tendency of avian frugivores to enter restored sites. It is unclear whether the number of frugivores in restored sites is mainly affected by how many occur in the surrounding vegetation or the attracting effects of remnant trees. In addition, the species diversity of remnant tree was not considered in previous studies due to limitations in the field (Zahawi and Augspurger, 2006; Lindell et al., 2013). The distribution and movement of avian frugivores are often highly related to tree species diversity (Gil-Tena et al., 2007). Therefore, it is important to examine the direct effects of remnant trees (both species diversity and coverage) on the entering tendency of avian frugivores.

In addition, studies (e.g., Zahawi and Augspurger, 2006; Fink et al., 2009) regarding frugivore visitation of restored forest sites have mostly been conducted in the tropics, where avian frugivores usually experience limited seasonal variation. Avian frugivores could exhibit different species compositions and behaviors among seasons in many parts of the world (e.g., Chen and Hsieh, 2002; Lindell et al., 2013). This seasonal variation may influence frugivore visitation but has mostly been neglected in previous studies.

In Taiwan, cultivation on mountainsides has been common at lower altitudes and has unfortunately intensified the potential for landslides because of the high precipitation, fragile sediments, steep topography, and frequent earthquakes. Since 2007, the Taiwan government has carried out the "Land Recovery Strategy" to reclaim some degraded lands and rehabilitate forests. Common approaches to this restoration project involve removing all agricultural crops, retaining native trees to function as remnant trees and planting seedlings of multiple native tree species. These restored sites vary greatly in the coverage and species composition of remnant trees and are randomly distributed within diverse vegetation types.

In this study, we investigated the effects of remnant trees and the surrounding vegetation on avian frugivore visitation of restored sites. Specific objectives were to determine (1) the avian frugivore composition in different surrounding vegetation types, (2) the tendency of avian frugivores to enter restored sites, and (3) the single and combined effects of remnant trees and surrounding vegetation on avian frugivore visitation of restored sites.

## 2. Material and methods

### 2.1. Study area

This study was conducted in restored sites within the Experimental Forest of National Taiwan University. The altitudes of the restored sites ranged from 400 to 1200 m above sea level. Climatic data from a nearby weather station (Sun Moon Lake, 780 m above sea level) revealed a mean annual temperature of 19.2 °C, with the highest mean monthly temperature in July (23 °C) and the lowest in January (13.2 °C). The average annual precipitation at the study site was approximately 2400 mm/year, with a dry season lasting from October to January. The native vegetation in this area is hardwood evergreen forests dominated by Lauraceae and Fagaceae. However, a large area containing native vegetation has been replaced with non-native bamboos (*Dendrocalamus latiflorus* and *Phyllostachys pubescens*), introduced conifers (*Cryptomeria japonica* and *Cunninghamia konishii*), tea, cabbage, and other agricultural crops. Restoration efforts have been conducted since 2009, including removing all the bamboos and agricultural crops, retaining most of the native trees and conifer plantations, directly planting seedlings of multiple native broadleaf trees and periodically weeding for 3 years. We established 30 restored sampling plots (Fig. 1) and 15 edge sampling plots in sites restored from 2009 to 2013 and located within different surrounding vegetation types. Each edge sampling plot was established at the edge of restored sites and in the vicinity of one or two restored sampling plots (detailed in Appendix 1). Due to the steep topography of the study area, many parts of the restored sites were not suitable for bird surveys. Therefore, we established the sampling plots randomly within the suitable areas of the restored sites. The 30 restored sampling plots were evenly distributed across the elevation range (Fig. 1) and varied in the coverage of remnant trees from 0% to 96% (Appendix 2). The 15 edge sampling plots were established in the vegetation surrounding the restored sampling plots using a stratified random approach. They were located within 3 vegetation types (hardwood forest, conifer plantation, and bamboo–hardwood forest), with 5 sampling plots in each vegetation type (Appendix 1). We did not establish edge sampling plots in farmland or shrubby land because these areas were too small. Previous studies (Hsieh et al., 2006; Ding et al., 2008) in the study area have found that 50 meters is

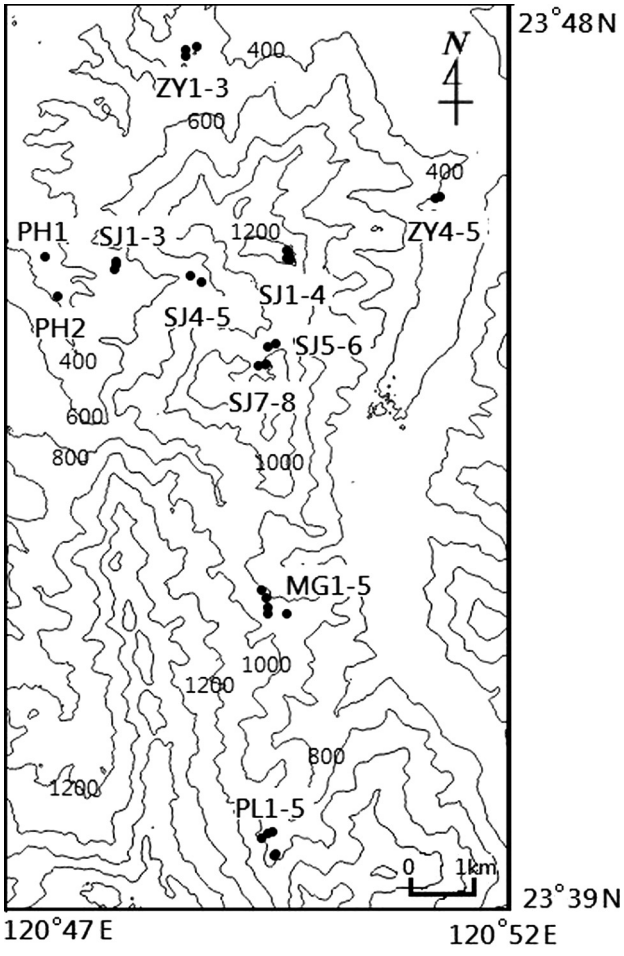


**Fig. 1.** Locations of all restored sampling plots and contour map (unit in meter) of the study area. The sampling plots are shown with black points.