



Effects of selective logging on rodent-mediated seed dispersal



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ABSTRACT

It is generally accepted that selective logging significantly influences the vegetation coverage and habitat structures, but little is known about whether and how low intensity selective logging affects seed dispersal mediated by small rodents. In this study, we compared the differences in seed disperser composition and abundance as well as primary and secondary seed dispersal and predation of *Quercus aliena* var. *acuteserrata* by scatter-hoarding rodents in different aged forest (i.e., unlogged stands, stands in the second and fifth year after low intensity logging 150 stems per ha) in Huoditang Forest in the Qinling Mountains, China. We found that the rodent composition of stands in the second year after logging (large-bodied disperser *Sciurotamias davidianus* was absent) differed conspicuously from that of the other two stands. Selective logging reduced the abundance of rodents, seed removal rate, scatter-hoarded proportion, and seed dispersal distance during the second year after selective logging. However, no significant differences were found in the composition and abundance of rodents as well as their seed dispersal services between the unlogged stands and in stands during the fifth year after logging. In addition, the proportions of initially buried acorns were significantly lower in stands in the second year after logging compared with the other two types of stands, but after seed caching, the seed revisiting rates were lower in stands in the second year after logging compared with the other two types of stands. Rodent-mediated seed dispersal was lower in the second year after selective logging but it recovered to its initial level within five years. The dispersal distance was significantly lower in stands in the second year after logging compared with the distances (3.12 ± 0.23 m) in the unlogged forest stands (5.75 ± 0.41 m) and in stands in the fifth year after logging (4.44 ± 0.36 m). Therefore, selective logging in forests is likely to temporarily alter the composition of rodent communities, change seed dispersal services, and the capacity for plant movements. Number of years after selective logging is important for determining whether seeds are removed rapidly by potential dispersers, which can lead to different rates of seed removal, seed predation, scatter-hoarding, and survival, and eventually influence forest recovery after selective logging.

1. Introduction

Many species of animals, especially rodents as well as birds, determine the structure and diversity of plant communities by caching plant seeds for future use and then forgetting about their locations (Vander Wall, 1990). Scatter-hoarding rodents can play an important role in the seed-to-seedling phase of plants, both as consumers and dispersers of seeds (Vander Wall, 1990; Perea et al., 2011; Hirsch et al., 2012; Jansen et al., 2014; Steele et al., 2014, 2015; Yu et al., 2015a,b; Zhang et al., 2016a). Numerous biotic and abiotic factors, e.g., predation, habitats, and human disturbance, may affect the seed hoarding behavior (cached plant seeds for future use) of rodents (Lai et al., 2014; Yu et al., 2015b; Yang et al., 2016), and subsequent seedling

recruitment (Smit and Verwijmeren, 2011; Yu et al., 2014a,b). In particular, previous studies indicate that seed dispersal patterns and plant regeneration can be affected greatly by human disturbance (Moran et al., 2004; Kirika et al., 2008a,b; Neuschulz and Farwig, 2011). Forest fragmentation and disturbance might negatively affect granivores communities and seed dispersal, thereby influencing the natural regeneration potential of local plant communities (Bleher and Böhning-Gaese, 2001).

Disturbances such as logging, can affect animal-mediated seed dispersal and the natural regeneration of plant populations by modifying various components of dispersal, i.e., detection, colonization, or recruitment (Markl et al., 2012; Zhang et al., 2016b). Logging causes important changes to the vegetation cover and structure in forests and it

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occurs throughout most of the world (Hansen et al., 2010). Logging generally involves removing the upper forest strata (i.e., canopy trees) which also allows more light to reach the forest floor, thereby encouraging growth of the understory. Current logging practices may remove minimal amounts of timber (e.g., low density selective logging) or most of the timber from the landscape (e.g., clearcut logging). Selective logging is an important economic activity in temperate and tropical forests (Lamanna and Martin, 2016a), and it is likely to affect tree population dynamics by causing abiotic and biotic (e.g., light, nutrients, and seed predation) changes (Gutiérrez-Granados, 2011; Haurez et al., 2016). Numerous studies have examined the impacts of different types of logging on animal communities (Gray et al., 2007; Burivalova et al., 2014; Lamanna and Martin, 2016b), where many have shown that logging can have very varied effects on species richness. However, it is still not fully understood whether and how selective logging might affect seed dispersal mediated by animals (Markl et al., 2012).

The effects of logging have often been studied by comparing biodiversity between logged and unlogged zones, but few considered the differences in the seed dispersal mediated by animals and subsequent forest regeneration between the two sites (Burivalova et al., 2014). Thus, it is very important to understand how forests regenerate after logging and the factors that can limit post-logging regeneration. There is a strong likelihood that logging-induced changes in the abundance and distribution of granivorous will lead to great changes in the seed dispersal services that they provide (Burivalova et al., 2014). Increasing the intensity of selective logging can also reduce the abundance of granivorous via decreased fruit availability and loss of forest structure (Lambert, 2011). Loss of cover is often associated with increased predation risk, which can affect the behavior of individuals by influencing their habitat use and access to resources (Spencer et al., 2005). If the abundance of animal seed dispersers is decreased, then fewer granivorous will visit fruiting trees (Neuschulz and Farwig, 2011), fewer seeds might be dispersed (Kirika et al., 2008a,b; Holbrook and Loiselle, 2009), and the dispersal distances of seeds could decrease in disturbed areas (Wright et al., 2000; Gutiérrez-Granados, 2011). Gutiérrez-Granados (2011) indicated that both the quantity and quality of seed dispersal are negatively affected by logging because of a change in the rodent scatter-hoarding dynamics. It has also been suggested that fragmentation and logging may have positive effects on seed dispersal (Farwig et al., 2006; Neuschulz and Farwig, 2011). However, previous study has suggested that selective logging (removal of all stems ≤ 3 cm in diameter of secondary-forest species) did not have an effect on seed removal (Andresen et al., 2005). It is possible that these contradictory results may reflect the impacts of logging on animal species that are highly dependent on the harvesting rates and time since logging, but few studies have investigated the different effects of number of years after selective logging on the abundances of animal species and subsequent seed dispersal (Haurez et al., 2016). This information would be very useful for the conservation of biodiversity in a changing world. Nevertheless, to the best of our knowledge, no previous study has assessed the effects of selective logging years on rodent-mediated seed dispersal. Thus, it is unclear whether different seed-dispersing animal groups (i.e., rodents) might differ in their response to selective logging years.

Previous studies of the effects of selective logging on seed dispersal have obtained inconsistent results, where the differences are most likely due to the differences in preferences between species. However, the effects of selective logging on the composition and abundance of the seed-dispersing mammalian community, as well as seed dispersal remain unclear. In China, *Quercus aliena* var. *acuteserrata* is a dominant species that contributes substantially to the stability and biodiversity of the forest ecosystem in the Qinling Mountains. This tree depends mainly on animals for seed dispersal (Yu et al., 2015a,b). In the Qinling Mountains, the effects of selective logging on gap regeneration have been investigated widely but no study has fully explored the ecological

effects of selective logging on *Q. aliena* var. *acuteserrata* seed dispersal by animals and subsequent regeneration (Sun et al., 2014; Chai and Wang, 2016). Thus, our understanding of the effects of selective logging on the recruitment of trees and its relationship with seed dispersal patterns remains poor, although selective logging is common in the Qinling Mountains. Additionally, most studies of seed dispersal only consider Primary movement, the initial movement of seeds from the parent tree; few investigations have indeed tackled the real final fate of acorns because of the complexity it entails. In this study, we followed up an initial evaluation of the disperser population conducted five years after the initial selective logging in order to assess the long-term impacts of logging on the composition and density of dispersers. We also continuously tracked individual *Q. aliena* var. *acuteserrata* acorns using coded plastic tags until they were finally eaten or left to germinate and explored the effects of small rodents on the dispersal of these acorns in unlogged stands, as well as in stands during the second year after logging, and in stands during the fifth year after logging, in the middle region of the Qinling Mountains.

In this study, we compared the differences in seed disperser composition and abundance as well as primary and secondary seed dispersal and predation by scatter-hoarding rodents in different aged forest. We addressed the following questions: (1) How does selective logging influence the composition and abundance of rodents? (2) Do the rodent-mediated seed dispersal and subsequent seedling establishment differ between unlogged and selective logging stands? (3) Does the number of years since selective logging have influence on the seed removal rate, seed fate and seed dispersal distance mediated by rodents? By answering these questions, we aimed to obtain a better understanding of the actual ecological effects of selective logging on rodent-mediated seed dispersal and to provide valuable information for forest recovery after selective logging.

2. Materials and methods

2.1. Study site

We conducted the experiment on the south-facing slopes at the Qinling National Forest Ecosystem Research Station in Huoditang Forest (108°21'–108°39'E, 33°18'–33°28'N), Ningshaan County, China. The forest was harvested during the 1960s and 1970s, and much of the area is now covered by secondary forests. The secondary forest dominated by *Q. aliena* var. *acuteserrata*, *Pinus tabulaeformis*, *Pinus armandii* in the tree layer and *Rubus corchorifolius*, *Smilax China*, *Symplocos paniculata*, *Euonymus salatus*, *Lonicera japonica* in the understorey vegetation. *Q. aliena* var. *acuteserrata* forest was selected, representing the most common forest type of the region. *Q. aliena* var. *acuteserrata* seedlings are shade-tolerant to some extent, but require more light during the subsequent regeneration stages. The forest cover and canopy closure levels are both $> 90\%$. We selected an area approximately 15.0 ha (fixed large plot) in the middle region of the Qinling Mountains as the experimental site. The site has been subjected to a selective logging management plan since 2011. The large plot was divided into the three stands and thus has a homogeneous environment before 2011. Three stands (approximately 240 m apart), i.e., unlogged stands, stands in the second year after logging, and stands in the fifth year after logging, were selected in secondary forests at the end of 2015. The three study stands are similar in elevation (1480 m), intensity of past land use, tree density (for stems ≥ 10 cm diameter at breast height: 1400–1500/ha), and floristic composition of the arboreal component (the top two dominants at three sites are *Q. aliena* var. *acuteserrata* and *P. tabulaeformis*). Same logging intensity with approximately 150 stems per ha (low intensity logging) was conducted in the stands in second year and fifth year after logging (Sun et al., 2014). If removal of 150 stems in secondary forests is done selectively, the survival/growth of *Q. aliena* var. *acuteserrata* saplings/trees may be favored. Some rodents, i.e., *Sciurotamias davidianus*, *Apodemus draco*, and *Niviventer confucianus*

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