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Short Communication

# Seed Dispersal of an Endangered *Kmeria septentrionalis* by Frugivorous Birds in a Karst Habitat

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**CL conceived and designed the study. GW, ZY, PC, WT contributed in field experiment work. CL and GW wrote the article.**

**Key words**
**Endangered species, Birds species, Behavior, Seed dispersal, Karst habitat, *Kmeria septentrionalis*.**

## ABSTRACT

Seed dispersal and plant regeneration in particular habitats by frugivorous birds are of great concern. In this study, we recorded the bird's seed foraging and dispersing behavior of local bird species to examine their role in dispersing seeds of *Kmeria septentrionalis*, an endangered tree species in a karst habitat in southwest China. Twenty-seven bird species were recorded feeding on its seeds, and fourteen bird species were confirmed as seeds dispersers. The chestnut bulbul (*Hemixos castanonotus*), striated yuhina (*Yuhina castaniceps*), scarlet minivet (*Pericrocotus flammeus*) were the main seed dispersers. The average seed dispersal distance was 10.69±4.97 m and 82% of the first post-foraging perching sites were located around 15 m from the mother trees. Our results suggest that the endangered tree species *K. septentrionalis* attracts native birds to forage and disperse its seeds in karst habitats, and that a high level of seed predation by ground-dwelling animals and microhabitat in karst unfavorable for seed germination might be the bottle-neck of its regeneration rather than the lack of seed dispersers.

Seed dispersal is considered an important process for determining the spatial structure, dynamics, and composition of plant populations (Heleno *et al*., 2013; Fonturbel *et al*., 2015). Previous studies have shown that 70-90% of seeds of plant species in tropics were dispersed by vertebrates (Arroyo-Rodríguez *et al*., 2017; Corlett, 2017). For example, birds consume a large number of seeds and disperse them by mechanisms such as carrying the seed via the gut or dropping them after chewing the pulp. In addition, birds have strong flight ability, so seeds in the feces could be dispersed a long distance from the parent tree with the daily movement. With the help of birds, seeds could reach a suitable habitat for germination, expand their area of distribution, and could avoid competition between offspring and parents, reducing predation and distance- or density-dependent mortality (Babweteera and Brown, 2009; Comita *et al*., 2014).

Southwestern China contains the most typical karst landforms in the world (He *et al*., 2012). Many endangered plants are distributed in this area, and a large number of seeds are produced every year; however, the dispersal process and seed fate are not clear. Although previous studies have shown that a large number of plant fruits or seeds in karst habitat are consumed by vertebrates (Ran *et al*., 1999; Pan *et al*., 2008; Su, 2008), there are no detailed studies on the role of animals in seed dispersal of the seeds of these endangered trees. Hence, studying the relationship between animals and plants in the karst region is important for the conservation and management of endangered plants in these habitats.

*Kmeria septentrionalis* is an endemic angiosperm native to China. It is only distributed in the karst habitats in northwest of Guangxi Province (Luocheng, Huanjiang), southeast of Guizhou Province (Libo) and southeast of Yunnan Province (Mali, Maguan) (Lin *et al*., 2011), thus it is on the IUCN endangered species list, as well as the key protected wild plants list in China (Nie *et al*., 2008). Most of the populations are randomly distributed; however, the only clumped distribution area is reported in Mulun National Nature Reserve. *K. septentrionalis* seeds become red after mature, and the seed shape and size (length: 1.14±0.15 cm; width: 0.49±0.06 cm; weight: 0.23±0.03 g, n=100) indicate that it relies on bird dispersal.

Some previous studies have suggested that the regeneration of wild populations could be limited by low germination rates in the karst habitat, where the low soil coverage, moisture and mineral content are unfavorable to its seed germination (Pan *et al*., 2008; Peng *et al*., 2015).

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Nevertheless, as an animal-dispersed tree, we still have no knowledge of it seed dispersal process of this species. The objective of this study was to evaluate the role of bird species in the seed dispersal of this endangered tree. We addressed the hypothesis that the endangered tree could attract local bird species to forage and disperse its seeds.

*Materials and methods*

This study was conducted in the Mulun National Nature Reserve (107°54′01″-108°05′51″E, 25°07′01″-25°12′22″N) in Hechi City, Guangxi Province, Southwest of China. Its total area is 10829.7 ha and its altitude ranges from 300-1,000 m above sea level. The annual average temperature is 19.3°C, with an average temperature of -5.0°C in January and 36.0°C in July. The annual average precipitation is 1529.2 mm, with rainfall mostly between June and September, and the mean annual relative humidity is more than 79% (Pan *et al*., 2008). Local vegetation was dominated by *Kmeria septentrionalis*, *Quercus glauca* and *Handeliodendron bodinieri* (Zeng *et al*., 2003).

Five mother trees were selected as the target trees during the seed maturation season from 20 September to 10 November, in 2016 and 2017. Observations were performed between the hours of 0630-1830 with binoculars, from a concealed location at least 20 m from the trees. Observations ended when no seeds remained in the mother trees. We recorded each bird visiting the tree and, noted its species, time spent in the tree from its arrival until it left the tree, number of seeds eaten during the visit, and seed handling behavior. If a group of conspecific bird species visited the tree and the behavior of all of the birds could not be observed simultaneously, we focused on the individual that was the most visible (Bascompte and Jordano, 2007; Li *et al*., 2015). We performed 720 h of tree observations and all observations were made in good weather.

**Table I.- Species of birds feeding on the seeds of *Kmeria septentrionalis* in the karst habitat of Mulun Nature Reserve, southwest China.**

| Bird species | No. of visits | | Seeds foraging per visit | Length of foraging | Feeding pattern | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | | | P | S |
| **Dispersers** | | | | | | |
| *Hemixos castanonotus* | 39 | 112 | 2.21±2.09 | 14.29±4.90 | 100 | 51 |
| *Yuhina castaniceps* | 11 | 72 | 1.93±1.74 | 10.42±4.02 | 38 | 45 |
| *Pericrocotus flammeus* | 21 | 43 | 3.58±2.25 | 13.11±5.50 | 51 | 13 |
| *Yuhina zantholeuca* | - | 29 | 1.17±0.46 | 8.90±3.53 | 17 | 12 |
| *Seicercus superciliaris* | - | 24 | 1.42±0.82 | 10.29±3.27 | 12 | 12 |
| *Alcippe morrisonia* | 20 | 21 | 3.83±3.66 | 11.15±5.65 | 32 | 9 |
| *Zosterops japonicus* | 25 | 26 | 3.17±3.02 | 13.45±6.83 | 43 | 8 |
| *Urocissa erythroryncha* | - | 21 | 2.29±1.42 | 24.24±9.32 | 16 | 5 |
| *Pycnonotus aurigaster* | 7 | 6 | 4.08±1.69 | 19.08±10.30 | 9 | 4 |
| *Seicercus castaniceps* | - | 18 | 3.39±3.39 | 11.67±8.49 | 15 | 3 |
| *Pericrocotus solaris* | 12 | 1 | 4.31±2.23 | 13.53±9.35 | 11 | 2 |
| *Parus spilonotus* | 2 | 8 | 1.1±0.3 | 9.40±3.14 | 9 | 1 |
| *Culicicapa ceylonensis* | - | 1 | 1 | 13 | - | 1 |
| *Muscicapa muttui* | 5 | - | 5±2.19 | 12±3.63 | 4 | 1 |
| **Consumers** | | | | | | |
| *Chloropsis hardwickii* | - | 1 | 1 | 8 | 1 | - |
| *Garrulax pectoralis* | - | 2 | 1 | 5 | 2 | - |
| *Phylloscopus inornatus* | 11 | 1 | 2.33±1.65 | 9.75±5.21 | 12 | - |
| *Seicercus poliogenys* | 4 | - | 2.75±2.49 | 17.25±8.81 | 4 | - |
| *Sylviparus modestus* | 21 | - | 13.31±5.74 | 9.90±3.48 | 21 | - |
| *Dicrurus macrocercus* | 4 | 10 | 2.64±1.23 | 14.86±6.01 | 14 | - |
| *Dicrurus hottentottus* | - | 1 | 3 | 9 | 1 | - |
| *Dicrurus leucophaeus* | 3 | - | 1.67±0.47 | 7.67±3.77 | 3 | - |
| *Niltava unicolor* | - | 1 | 1 | 9 | 1 | - |
| *Cyanoptila cyanomelana* | 4 | 2 | 1.5±1.18 | 8.17±3.53 | 6 | - |
| *Myophonus caeruleus* | - | 1 | 2 | 26 | 1 | - |
| *Paradoxornis webbianus* | 3 | - | 9.67±3.09 | 9.67±3.09 | 3 | - |
| *Aegithalos concinnus* | 3 | - | 13±2.94 | 4±2.16 | 3 | - |

Feeding pattern: S, swallow; P, peck. Data are based on five mother trees.

We defined the bird species that swallowed the seeds or carried the seeds away in their beaks as seed dispersers, whereas seed consumers pecked the seed arils (Li *et al*., 2016). The first post-foraging perching site of each seed disperser was recorded after it left the mother trees, and a Laser Range Finder (NewconLR7×40) was then used to measure the distance between the perching site and the mother trees. We assumed that the first post-foraging perching site was a sufficient proxy for evaluating the effects of seed dispersal (Breitbach *et al*., 2010; Spiegel and Nathan, 2012). To evaluate and visualize the relationship between the perching frequency and distance to the mother tree, we calculated the perching frequency in six distance classes (5 m intervals from 5-30 m from the mother tree) based on field observation data of first post-foraging perching sites (Li *et al*., 2015). We used *t*-tests to compare the difference in visiting frequency between years. A p-value of <0.05 was considered to be statistically significant according to Shabana *et al*. (2018).

*Results*

During the mature season, we recorded 195 visits by 17 bird species in 2016, and 401 visits by 21 bird species in 2017. Eleven bird species were common visitors during both years (Table I), but the visiting frequency did not significantly different between the years (*t*-test, $P > 0.05$). Among these bird species, chestnut bulbul (39 visits), Japanese white-eye (25 visits), scarlet minivet (21 visits) were the main foragers in 2016, and the chestnut bulbul (112 visits), striated yuhina (72 visits), and scarlet minivet (43 visits) were the main foragers in 2017, respectively. The red-billed blue magpie spent the most time foraging in the trees, and yellow-browed tits consumed the most seeds per visit (Table I).

Only 14 bird species that swallowed the seeds could be confirmed as seed dispersers among all 27 seed-eating bird species (Table I), many birds pecked the pulp of the seeds on the tree and did not carry the seeds away from mother tree, so they were not classed as effective dispersers. The contribution of seed dispersers was different, and their visiting frequency was significantly different (*t*-tests, $P<0.05$). Among the dispersers, the chestnut bulbul, striated yuhina, scarlet minivet were the mainly seed dispersers, and their visiting frequencies were 30.5%, 26.9%, and 7.9%, respectively.

We recorded 167 first post-foraging perching sites of effective dispersers in the karst habitat. The average seed dispersal distance was 10.69±4.97m and 82% of the first post-foraging perching sites were located around 15 m from the mother trees, but then decreased with increasing distance to the source patch (Fig. 1).

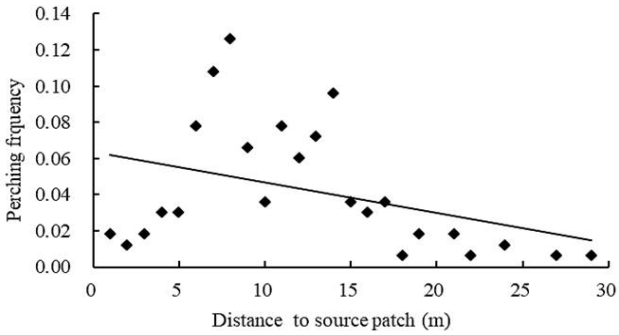


Fig. 1. The perching frequency of dispersers at different distances from the source of Kmeria septentrionalis in the karst habitat of Mulun Nature Reserve, southwest China.

*Discussion*

Our study demonstrated that *K. septentrionalis* tree could attract local birds to disperse its seeds, and seed dispersers transported the seeds away from the mother tree and ultimately influenced the spatial distribution of seedlings. As many as 27 bird species were observed to feed on *K. septentrionalis* seeds, and two possible reasons may explain this. First, mother trees with red seeds could form strong advertising effects as other bird-dispersed fleshy fruit plants (García *et al*., 2010; Rodríguez *et al*., 2013), to attract local birds to feed on its seeds (Table I), Moreover, the red seeds did not fall off immediately, but remained suspended from the outer shell of the fruit by a white filament, which can prolong the feeding duration to attract more birds to feed on them. Second, there are few ripe fleshy fruits in the karst habitat in autumn during the mature season of *K. septentrionalis*. During our two years of field observations, we did not find any co-ripening fruits with *K. septentrionalis* in the study site, so their seeds were a major resource during this time of food scarcity.

In our study, 14 bird species were classed as seed dispersers (Table I), the high number of dispersers means that more seeds were removed from the mother tree, which increased the chances of colonization in new habitats (Schupp *et al*., 2010). Additionally, the average seed dispersal distance was 10.69±4.97 m (Fig. 1), which was less than the seed dispersal distance in disturbed habitats (Şekercioğlu *et al*., 2015), this may be related to the habitat characteristics. Our study was performed in the small nature reserves of *K. septentrionalis*, where there is less human disturbance and greater vegetation cover; such suitable habitats can provide a safe foraging site for birds, so that they do not need to fly far away after feeding.

In the field research period, we could only find a few seedlings near the research site. Our results showed that *K. septentrionalis* did not lack seed dispersers, and the reason for its endangered status may be related to other factors.

For example, the seeds contained an abundance of oils (Huang *et al*., 2010), so after it reaches the ground it could face high levels of seed predation by ground-dwelling animals. Furthermore, it may be influenced by the dispersal distance, and the karst habitat (shallow soil, low moisture and mineral contents) is unfavorable for seed germination. In the future, we should consider how ground-dwelling animals influence the fallen seeds, and their role in the regeneration of this endangered tree species.

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*Statement of conflict of interest*

The authors declared that there is no conflict of interests regarding the publication of this article.

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