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Short communication

Diverse nectar robbers on *Alpinia roxburghii* Sweet (Zingiberaceae)

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ABSTRACT

This study records for the first time three mammal species as nectar robbers on the ginger *Alpinia roxburghii* Sweet. We examined the behavior of nectar robbers and compared with earlier studies on a single plant species. We recorded seven species of nectar robbers: three squirrels, one bird, and three bees. Timing of robbing nectars were similar; however, robbing behavior differed among robbers. In particular, squirrels damaged the flower parts while robbing the nectar.

Introduction

Numerous species of insect, in addition to various birds and some mammals fail to pollinate flowers as legal pollinators, by changing their behavior to remove nectar without pollinating various plant species (Adler and Irwin 2006; Arizmendi et al 1996; Castro et al 2008; Hernandez and Toledo 1979; Lyon and Chadek 1971; Irwin 2003; Roubik 1982; Zhang et al 2013). Nectar robbing of various plant species is common in tropical and temperate forests (Irwin et al 2010; Mayer et al 2014; Singh et al 2014; Zhang et al 2013). Although nectar theft is not uncommon by insects or birds, it has not been recorded in many legitimate mammal pollinators (i.e., bats) (Devy and Davidar 2003; Sazima et al 1999).

However, some rodents have previously been shown to display nectar robbing behavior, with ginger species bringing a frequently victimized taxa for nectar theft. In an earlier study *Alpinia roxburghii*'s sister species *Alpinia kawengensis* was also found to be the subject of nectar theft by striped squirrels (Deng et al 2004). Nevertheless, some earlier studies report different nectar robbers victimizing a single plant species (Guitan et al 1993; Roubik 1982; Wilmer and Corbet 1981), but this phenomena has not been studied in detail. Therefore, nectar robbers on ginger species could be a relevant topic to understand ecological consequences.

Several studies have reported negative, positive, and neutral effects of nectar robbing on male and female fitness. For instance, nectar robbing bees have been shown to have positive (Maloof and Inouye 2000; Singh et al 2014), neutral (Navarro 2001), and negative effects (e.g,. Irwin et al 2001; Irwin and Brody 1999; Roubik 1982; Traveset et al 1998; Zhang et al 2007), on reproduction in a number of plant species. Some studies report that nectar robbers may cause floral damage in certain situations, but little is known or has been recorded about the nectar theft by mammals. This study aims to determine how species actively steal nectar from *A. roxburghii*, and their interactions and timing of nectar stealing events by different robbers.

Materials and methods

Study site and species

The study was conducted in Caiyanghe Provincial Nature Reserve (22°30′N, 101°22′E), south west China at 1200 m above sea level. The *A. roxburghii* population in the study area extends over a large area of the evergreen broad leaved forest along several valleys and is a dominant understory species. *A. roxburghii* Sweet (Zingiberaceae) is a hermaphrodite flexistylous perennial herb, usually 1–3 m tall (Deng et al 2005; Zhang et al 2003), with a large inflorescence on leafy shoots 20–40 cm long. The peak flowering period is from March to late April and fruiting lasts from April to

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September, with a single flower lasting 1 day (5:30 AM to 20:00 PM). It is a self-compatible species and attracts diverse pollinators due to high secretion of nectar throughout the day (Deng et al 2005). This species has large corollas that facilitate a comfortable platform for many pollinators (Zhang et al 2003).

Interestingly, *A. roxburghii* shows flexistyly floral dimorphism evolved through changing the position of the style and separating maturation of male and female organs, which differ in the direction of style movements (Cui et al 1995; Takano et al 2005; Zhang et al 2003). Two types of flexistyly are used by A. roxburghii, i.e., cataflexistylous (protandrous) style and anaflexistylous (protogynous) style. Cataflexistyly involves upwards curved styles when pollen is dispersed in the morning. During this time, stigmas are spatially separated from anthers and pollinators have no chance to contact stigmas, which may additionally be unreceptive. In anaflexistyly, the styles move downward during afternoon. During this stage, pollinators can contact stigmas may cross-pollinate. Therefore A. roxburghii uses cataflexstylous and anaflexistylous adaptations to promote higher outcrossing that enhance fruit set (Zhang et al 2003; Sun et al 2007), the effect of such adaptations on various aspects of reproductive success has been published in several previous studies (Li et al 2001; Li et al 2002; Sun et al 2007; Zhang et al 2003).

Observation of nectar robbers were made in 2005–2007. We observed and randomly photographed nectar robbers from 5:30 AM to 20:00 PM in the study site where the area is about 30 ha during our observations. Bees and squirrels were the most common nectar robbers and bird species were rarely found. Robbing species were identified to species level using faunal key character and confirmed at the Kunming Institute of Zoology museum. We observed robbing visits of striped squirrels and recorded the number of robbed flowers and broken styles in three successive

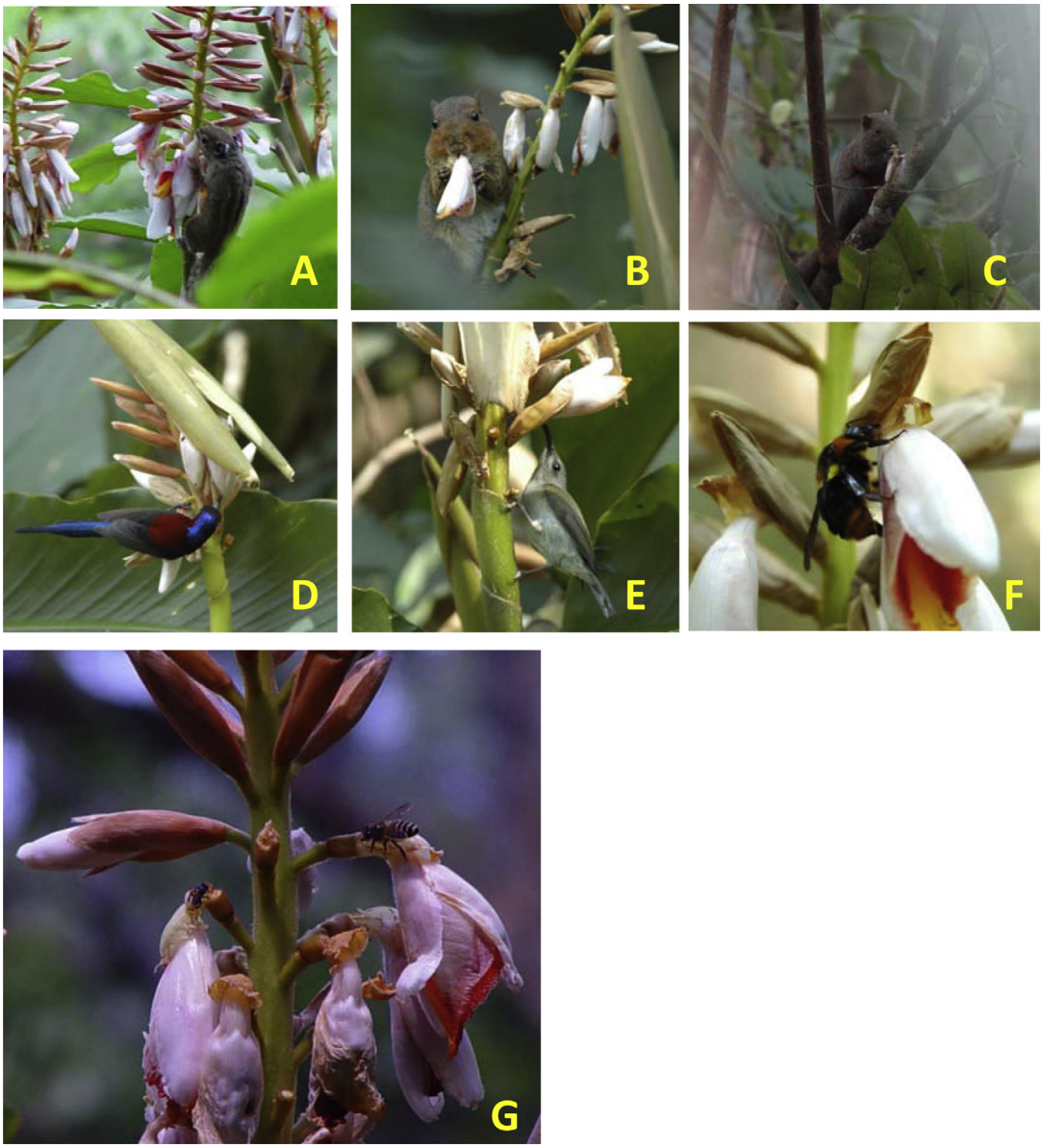

Figure 1. Photographs of diverse nectar robbers on *Alpinia roxburghii*: A, *Tamiops swinhoei* (the important primary nectar robber striped squirrel; B, *Dremomys rufigenis* (accidental primary nectar robber); C, *Callosciurus erythraeus* (Mountain Red-bellied Squirrel, accidental primary nectar robber); D, *Aethopyga siparaja seheriae* (male sunbird, primary nectar robber but not very often); E, *Aethopyga siparaja seheriae* (female sunbird, primary nectar robber but not very often); F, *Bombus richardsi* (big size bumble bee acts as primary nectar robber); G, *Apis cerana* (on the right) and *Trigona (Heterotrigona) pagdeni*. (stingless bee on the left), both act as secondary nectar robbers.