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(Research Article)

Artificial light reduces the visitation of nectar-feeding bats to *Musa balbisiana* flowers, a preliminary study in Yunnan, China

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Abstract

The impact of artificial light on bat activity has been extensively studied in insect-eating bats but remains incomplete for fruit bats, particularly nectar-feeding bats, which play a crucial role in pollination. In the Xishuangbanna Tropical Botanical Garden rainforest, we illuminated *Musa balbisiana* inflorescences with various lights to examine the effects on nectar-feeding bats' foraging activity. Our results indicated that both white and red lights negatively affected bat visitation. The average number of bat visits over 2 hours in the evening decreased from 12.4 ± 9.5 with no light to 7.9 ± 7.3 with infrared light, 1.8 ± 2.6 with red light, and zero visits with white light. Consequently, the proliferation of artificial lights worldwide could reduce the ecosystem services provided by these bats. During the study, *Macroglossus sobrinus* Andersen, a nectar-dependent bat, was captured using mist nets, and two other potential bat species were observed and discussed.

Keywords: Artificial Light; Nectar-Feeding Bats; Pollination; Tropical Rainforest; Wild Banana

1. Introduction

Bats are the second largest order of mammals, comprising over 1,300 species (Fenton and Simmons, 2015). Old World fruit bats are especially important as pollinators and seed dispersers, aiding in the maintenance of natural vegetation and the recolonization of cleared forest areas (Mickleburgh et al., 1992). Approximately 528 species of ecologically and economically significant angiosperms rely on nectar-feeding bats for pollination (Fleming et al., 2009).

However, bats are facing multiple challenges, including the loss of original tropical forests, conflicts with fruit growers (Mickleburgh et al., 1992), and the negative impact of artificial light (Lewanzik and Voigt, 2014). The increasing number of areas illuminated at night (Bennie et al., 2015) poses a significant threat. Studies on insect bats show that strong white or yellow light restricts their movement and makes them more vulnerable to predators, whereas red light does not have the same effect (Spoelstra et al., 2017). Research on the impact of light on nectar-feeding bats is sparse and incomplete. For instance, nectar-feeding bats increase their foraging activity on dark nights compared to moonlit nights (Elangovan and Marimuthu, 2001; Singaravelan and Marimuthu, 2002), but avoid or consume less from illuminated flowers (Nuevo Diego, 2018; Watzke, 2006; Lewanzik and Voigt, 2014). Additionally, Nuevo Diego (pers. com.) noted that bat capture rates were lower with camera trapping compared to personal observations of bat visitations, and no bats were captured when red light was used to illuminate flowers. Furthermore, there have been no studies on the effect of light on the foraging activity of nectar-feeding bats.

This paper synthesizes findings from previous studies on various types of light—white light, red light, infrared light (IR) from camera traps, and no light—to examine their effect on the foraging activity of nectar-feeding bats in a tropical

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rainforest. We hypothesize that fewer bats will visit illuminated flowers, predicting a decrease in bat visitations from no light to IR, to red light, and finally to white light.

2. Methodology

2.1. Study area

This study was conducted in the rainforest of Xishuangbanna Tropical Botanical Garden, Chinese Academy of Science (XTBG), located in Menglun, Yunnan province, southwestern China, at an altitude of 578 meters (21.91809 N, 101.27462 E). The rainforest is an ecologically preserved area with permanent stands of banana plants (Figure 1).

The study utilized twenty-three inflorescences from nine groups of banana plants, which were distributed irregularly but mainly along the edges of two trails. The entire study area spanned approximately 500 meters in length from east to west (Figure 2) and was completely devoid of artificial light, except when people visited carrying lights.

Figure 1 A permanent stand of bananas located inside the Xishuangbanna Tropical Botanical Garden's Rainforest area.

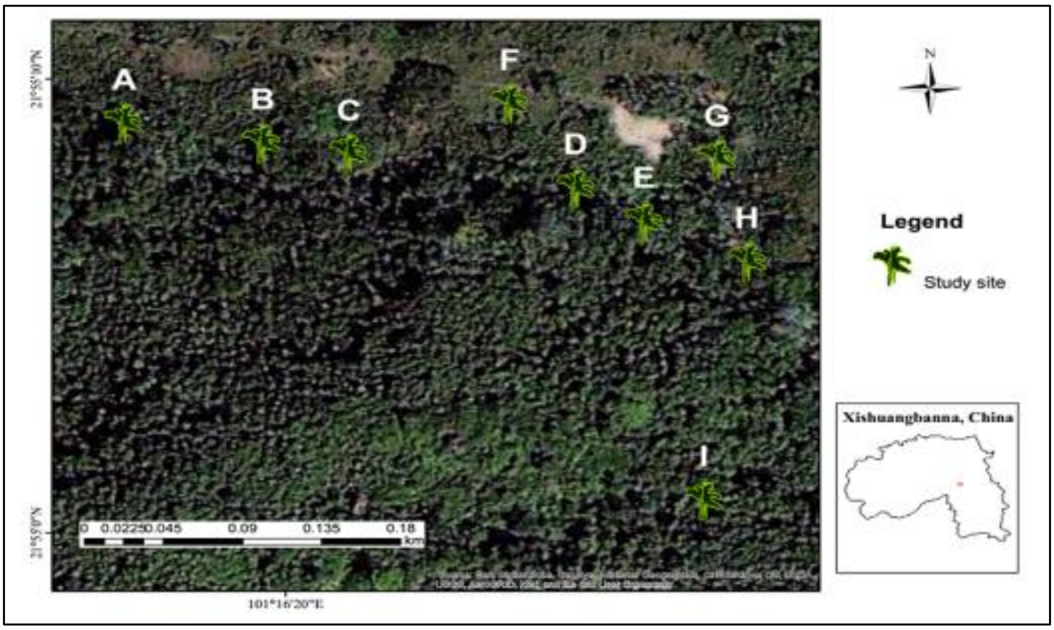

Figure 2 The study site and the locations of each banana plant groups in Xishuangbanna Tropical Botanical Garden's Rainforest area

2.2. Study species

Musa balbisiana, commonly known as wild bananas, are large fruit crops that can grow up to nearly 5 meters in height. They thrive in various habitats, including moist evergreen forests, secondary growth forests, and semi-disturbed areas (Williams, 2017). In XTBG, *M. balbisiana* flowers are typically found over 5 meters above the ground. The inflorescences are arranged linearly under each reddish bract, and anthesis is marked by the opening of the bract, which progresses from the base to the apex of the inflorescence (Itino et al., 1991). The structure and flower phenology of *M. balbisiana* prevent pollen transfer within the same inflorescence (Itino et al., 1991).

2.3. Treatments

Samplings were performed from 10th to 24th November 2018 on *M. balbisiana* inflorescences selected in the afternoon before observation night. These inflorescences were then subjected to 4 different treatments: (1) no light (control) treatment, (2) Infrared (IR) treatment using the IR emitted by a camera trap (LTL ACORN Ltl-6511 MC, China) installed 2-3 m from the inflorescence, (3) red light treatment, and (4) white light treatment. Red and white light torches, emitting similar light intensities, were set 3-4 m far away from the banana flowers. Thermal cameras (FLIR-T7250 and FLIR-T62101, Wilsonville, Oregon, United States) were used to observe bat behavior in control and IR treatments while the naked eye was enough to observe red and white light treatments. The lights were on for 2 h in the forest (19:00 – 21:00 h). At this time bat visitations and behavior were counted and noted by direct observation or by video recordings using the thermal cameras. Several inflorescences were observed simultaneously in different banana groups each night. Mist netting was conducted once (19:00 – 21:00 h) to catch bats for identification, with the nets positioned near banana flowers. Bats were identified using Francis (2008).

2.4. Statistical analysis

Results were analyzed using Generalized Linear Mixed Model (GLMM). Two fixed effects (light treatment and moon phase) and two random effects (banana groups and flower from respective individuals) were included in the full model. Hypothesis testing was conducted by comparing Akaike Information Criterion (AIC) values. The models were not significantly different from each other. Therefore, the simpler model was selected. This excluded moon phase but included all the others (Table 1). Moreover, this simpler model is significantly different from the rejected null model which had no fixed effect and assumes the treatments do not affect the response of bat visitations on flower under different illuminations (ANOVA, $\mathcal{X}2$ = 63.411, df = 6, P < 0.001).

Table 1 Model selection using AIC values. The simpler model was chosen since the two AIC values were not significantly different from each other.

Model	**AIC**	**df**	**Deviance**
visitations + 1 ~ Treatment + (1 | Group/Banana)	198.30	6	186.30
visitations + 1 ~ Treatment + Phase + (1 | Group/Banana)	199.44	7	185.44

All mean values are presented here as mean ± SD.

3. Results

3.1. Bat visitations

From the observations in the no light treatment, we were able to classify bat visiting the *M. balbisiana* flowers into 3 groups of bats: one that foraged in a group and two that foraged solitarily. For the solitary bats, there were smaller and bigger bats. The most common visitor we observed belonged to the small solitary bat group. The big solitary bats and the group foragers were only observed twice and once, respectively, in the same night. However, mist netting only captured one bat, a *Macroglossus sobrinus* Andersen (Figure 3), which is a nectar-obligate bat highly associated with banana flowers (Itino et al, 1991; Stewart & Dudash, 2018).

Figure 3 *Macroglossus sobrinus* was the only bat being captured during mist netting

In the four treatments, the mean number of bat visitation gradually decreased from no light treatment (12.4 ± 9.5), infrared (7.9 ± 7.3), and red-light treatments (2.6 ± 1.8), while there were zero bat visitations for white light treatment (Figure 4). Statistically, the difference between the mean number of bat visitations in response to illumination is significant between control and red (GLMM, $P < 0.001$), control and white (GLMM, $P < 0.001$), IR and red (GLMM, $P < 0.001$), and IR and white (GLMM, $P < 0.001$). However, the mean bat visitations between control and IR as well as red and white treatments were not significantly different (GLMM, $P = 0.737$ and $P = 0.201$, respectively).

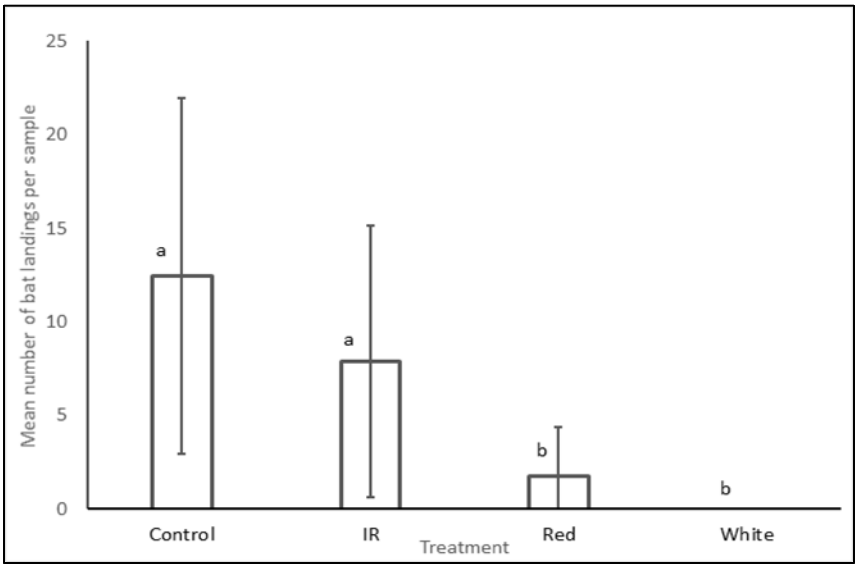

Figure 4 Bat visitations in response to illumination gradually declined from no light, IR, red light, to white light treatments. The error bars represent standard deviation and the different letters above treatment bar chart indicate it is statistically significant differences

4. Discussion

Our prediction that there will be more bat visitations in the control (no light), then infrared, then red light, and lastly white light treatments were supported by our results. Our results for the control treatment showed that the study site has a good number of nectar-feeding bats. It also allowed us to see the normal foraging behavior of these bats. Bats normally flew straight for the flowers and left after a second. In this treatment, we observed 3 groups of bats, and we assume that *M. sobrinus* belonged to the small solitary bat group and that there are possibly two more species of bats visiting the *M. balbisiana* flowers but were not caught by our mist nets. *M. sobrinus* is a small nectar-feeding bat that weighs between 19-29 g (Francis, 2008) and was observed by Start and Marshall (1976) to forage singly. On the other hand, we assume that the bats that forage in groups were *Eonycteris spelaea* Dobson as these were observed by Start and Marshall (1976) to forage in groups and were previously captured in the area, although not by our own mist nests.

Both *M. sobrinus* and *E. spelaea* are also known to feed on *M. balbisiana* nectar (Stewart & Dudash, 2018). The bigger solitary bat group we expect to be *Rousettus leschenaulti* Desmarest since it was also previously caught in the area (Tang et al., 2012) and is bigger than *M. sobrinus* and *E. spelaea* (E. spelaea: 45-60 g and R. leschenaulti: 60-100 g; Francis, 2008).

For infrared light treatment, bats were observed to go near the flowers: Some of them landed on the flowers while others flew away at the last second. The samples could be classified into 2 groups: low number of visitations (0-8 visitations from 6 samples) and high number of visitations (14-20 visitations from 3 samples). Unfortunately, we could not identify the bats in flight and could not tell if the bats belonging to the low visitation group is different from the high visitation group. However, assuming that the bats were the same species in both groups, we could attribute the different bat behaviors to the intensity of the IR light or other behaviors the individual camera traps had. We used the same brand and model of camera traps and set them all up at approximately the same distance from the flowers. However, because we were unable to calibrate IR light nor could we see it, we could not guarantee that the IR light intensity was the same for all the camera trap units that we used.

For red light treatment, we observed that most bats would fly around the flower but outside the beam of red light and fly away. Liu et al., (2002), observed bat visitation frequencies of the same species bats, *M. sobrinus* to *Musa itinerans* Cheesman flowers were low when illuminated by red light. Combined with our results, it can be seen that the effect of red light on the pollination of fruit bats is significant. So that, although red light does not have a negative effect on insect bats (Spoelstra et al., 2017), it does on nectar-feeding bats. And biologists who use red light to observe nectar-feeding bats should be aware that their data collection is biased against bats that are averse to red light. Lastly, the white light treatment resulted in zero bat visitations. This confirms that white light is a deterrent to nectar-feeding bats, at least if and until they get used to the light. This is definitely the case for *M. sobrinus*, which we caught in the study site, as well as two other possible nectar-feeding bat species that we were not able to catch but may not be applicable for other nectar-feeding bat species. If the bats are not able to overcome their dislike for light, this will reduce their ecosystem services and will impact fruit production and reproductive success of plants that are dependent on bats for pollination.

4.1. Implications for Conservation

Different bats have different reactions to illumination. By allowing the increase of light pollution, we are effectively narrowing down the food available to nectar-feeding bats and decrease reproductive success in plants that are dependent on them for pollination. As our forests decrease and our artificial lights increase, we may slowly be dooming not only the nectar-feeding bats, the plants that depend on them, but also affect other creatures that depend on these plants for survival.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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