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โครงการวิจัยเรื่อง

อิทธิพลของนกกินแมลงและค้างคาวกินแมลงในการควบคุมแมลงศัตรูพืช

ในลองกอง (Lansium domesticum Corr.) ในภาคใต้ของไทย

Impact of insectivorous birds and bats on the agricultural pest control of *Lansium domesticum* Corr. in southern Thailand.

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อิทธิพลของนกกินแมลงและค้างคาวกินแมลงในการควบคุมแมลงศัตรูพืชในลองกอง (Lansium domesticum Corr.)ในภาคใต้ของไทย

Impact of insectivorous birds and bats on the agricultural pest control of *Lansium domesticum* Corr. in southern Thailand.

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ABSTRACT

Insectivores are important in regulating arthropod populations, and the regulation of crop pests is of particular interest to humans. The purpose of our study was to dissect insect pest control into two components: nocturnal pest regulation by bats and diurnal pest regulation by birds. We executed our study by imposing one of four treatments (excluding bats, excluding birds, excluding both, excluding neither) to our experimental trees and compared arthropod abundances. We found a significant effect of treatment level on arthropod density that the excluding bat has higher arthropod density than control and bird excluding. Insectivorous bat play an important role in insect control in farmland near the forest.

INTRODUCTION

Nature provides us with many ecosystem services, some of which we are just beginning to realize and understand. These services come from different sources and have varying impacts. Some of the most important services for humans include those that help agriculture, such as pollination, soil aeration and enrichment, and pest control (Losey & Vaughan 2006). Therefore, studying these processes is very beneficial and has the potential to greatly help agricultural crops.

Pest control is one of the more complex processes, as various crop, arthropod, and insectivore species create an intricate food web (Janssen et al. 1998; Cohen et al. 2004). Furthermore, some arthropod species are helpful to farmers while others are harmful. Understanding the numerous interactions is important in learning how to maximize the benefits of biological pest control.

Early studies of pest control tended to focus on diurnal insectivores, however, they failed to take into account the effects of nocturnal insectivores such as bats (Holmes et al. 1979; Gradwohl and Greenberg 1982; Atlegrim 1989; Marquis and Whelan 1994; Greenberg et al. 2000; Van Bael et al. 2003; Van Bael & Brawn 2005; Mooney and Linhart 2006). Yet bats can be just as important as birds, or even more so, in controlling arthropod populations (Kalka et al. 2008; Williams-Guillen et al. 2009).

More recent studies have focused on the role of bats in pest control and compared them with insectivorous birds (Kalka et al. 2008; Williams-Guillen et al. 2009). But while they differentiated between the overall effects of diurnal and nocturnal insectivores, they did not investigate how the activities of these two groups differed. Understanding the foraging activities of each is important because it is likely that birds and bats occupy complementary niches. For example, birds consume diurnal arthropods while bats consume nocturnal arthropods. Additionally, Williams-Guillen et al. (2009) showed that birds had a larger effect in the dry season while bats had a larger effect in the wet season. And insectivorous birds and bats are likely to have different effects on different arthropod species, depending on the manner of foraging (e.g., substrate-gleaning versus aerial-hawking) (Holmes & Recher 1986).

Furthermore, the vast majority of insectivore-exclusion studies have been performed in forests (Holmes et al. 1979; Altegrim 1989; Marquis & Whelan 1994; Van Bael et al. 2003; Van Bael & Brawn 2005; Mooney & Linhart 2006; Kalka & Kalko 2006; Kalka et al. 2008). While this information is useful, it is not aimed to help farmers, and agricultural areas typically have fewer birds and bats than forests (van Dorp and Opdam 1987; Estrada et al. 1993; Cosson et al. 1999). Therefore, this study will examine if insectivorous birds and bats have an impact in areas where they have lower population numbers. Also, this study will be the first insectivore-exclusion experiment to be performed in fruit orchards, so we will test the pest control of frugivorous arthropods in addition to folivorous arthropods.

As key pest control agents, both insectivorous birds and bats help farmers, and as a result they benefit us all. While previous studies have made broad comparisons of the two, none have looked at the specific feeding activities of each. The foraging behavior of insectivorous birds and bats may explain why certain agricultural pest patterns exist. This study intends to examine this possibility, and will hopefully reveal information that will be useful to both local Thai farmers, as well as to those in other tropical countries.

METHODS

Study site

Our study was conducted in organic, mixed fruit orchards at Khao Phra, Songkhla province (7°1'N, 100 °9'E) over a 12 week period (August - November 2009). The dominant species in our study area were longkong (ลองกอง *Lansium domesticum* Corr.), chempedak (จำปาดะ *Artocarpus integer* Merr.), durian (ทุเรียน *Durio zibethinus* L.), mangosteen (มังคุด *Garcinia mangostana* L.), banana (กล้วย *Musa acuminata* Colla), and coconut (มะพร้าว *Cocos nucifera* L.). Surrounding habitat consisted predominantly of lowland and limestone karst forests.

Experimental set-up

Although the orchards we worked in contained several types of fruit, we limited our study to testing only longkong (*Lansium domesticum* Corr.). This species was chosen due to its economic importance in Thailand. Additionally, its relatively small size compared to other tree species facilitated the execution of our experimental set-up.

We used 4 treatments (bat-excluded, bird-excluded, both-excluded and control) and therefore trees were chosen in blocks of four. Within the study area, there were slight differences in microhabitat (i.e. amount of sunlight, proximity to bodies of water, density of surrounding vegetation) so blocking helped control for this variation. We selected 18 blocks for a total of 72 trees. In order to feasibly cover the trees with netting, we selected trees ranging between 1.5 to 3.5 m tall (2.54m ± 0.62m), thus they were immature (i.e., unable to yet fruit).

Prior to the start of our study, frames were built around each of the experimental trees. These frames were left in place throughout the duration of the study and, for 3 of the treatments (bat-excluded, bird-excluded, both-excluded), supported the simple pulley system which raised and lowered the exclosure netting.

Each frame consisted of four bamboo poles (taller than the experimental tree) which were evenly spaced around the perimeter of the tree and secured upright. A simple pulley system was rigged by drilling a hole through the top of each pole and passing rope through each hole. Netting was tied to each of the 4 strands of rope, so that pulling on the free ends of the ropes raised the walls of netting. The netting covering the top side of the frame was placed on at the start of the study and untouched throughout the duration, as there was no quick and simple way to remove and replace it. Control trees were not enclosed by walls of netting, but frames and netting covering the top of the frame were installed to create conditions like the other 3 treatments. All netting used had a mesh size of 2.25 x 2.25 cm and was made from nylon twine 0.15 mm thick.

The netting was raised and lowered in a consistent manner throughout the 3-month study. Bat-excluded trees were covered during the night; the netting was pulled into place at dusk and removed at dawn. Bird-excluded trees were covered during the day; netting was pulled into place at dawn and removed at dusk. The netting for the both-excluded trees was constantly left up while the control trees were never enclosed.

<u>Arthropod abundance</u>

At the start of the study, we censused the arthropods on each tree. Thereafter, censuses were performed weekly. Censuses were conducted by examining both sides of each leaf for non-colonial arthropods. After determination that the arthropod composition of the bottom halves of the trees was not significantly different from the top halves, censuses were restricted to leaves no higher than 2 m above ground (the height that could be easily reached without use of a ladder). Twenty-six out of the 72 trees were less than 2 m (100% of leaves censused) while the remaining 46 had between 60-90% of their leaves included in the census. The number of leaves surveyed per tree was estimated, and the density of arthropods per leaf was calculated for each experimental tree.

Arthropods were categorized to the level of Order and were left on the tree untouched, except for unfamiliar specimens which were bagged and brought back to university for identification. The order in which blocks were examined varied between weeks. Within each block, the order of the 4 treatments was random.

<u>Bird activity</u>

Once a week, we patrolled the study site and recorded bird activity. Individuals were identified with the help of binoculars and a bird guide (Lekagul and Round). For each bird spotted, we noted the species, time of observation, and location (which area of the study site). For birds observed perching, we also recorded which forest layer (ground, understory or canopy) and which species of plant they perched on.

<u>Bat activity</u>

An Anabat bat detector (Titley Electronics, Ballina, Australia) was left at the study site and recorded ultrasonic noise from 1800 to 0600 hours every day. The location of the Anabat was rotated throughout different areas of the study site weekly. Calls were analyzed using Analook (version 3.3q, C. Corben).

Data analysis

All analyses were performed with SAS version 9.2 (SAS Institute 2007). For testing the effect of treatment on arthropod abundance, data were pooled by tree across the 12 weeks and, as the data could not be normalized by transformation, analyzed with nonparametric tests. A Friedman's Test was performed, which accounted for the block effect as well as the treatment effect. Multiple comparisons were performed to test for significant differences between treatment levels.

RESULTS

Arthropod abundance

A total of 13 known arthropod orders were observed over the course of the 12 census measurements (Table 1). By far the most abundant insect were Diptera (45.3 %), and Coleoptera (14.0 %). The remaining orders each accounted for 0.03-3.4% of all observed arthropods. Spider (Araneae) was also abundant (23.6 %).

The average number of arthropods per leaf was 0.329 (SD=0.10) for the bat-excluded treatment, 0.262(SD=0.14) for the bird-excluded treatment, 0.277 (SD=0.11) for the both-excluded treatment and 0.239 (SD=0.09) for the control (Figure 1). Bat exclusion had the highest insect density followed by both exclusion, bird exclusion and control. Treatment had no significant effect on arthropod abundance (GLM, p=0.107). However, when Mann Whitney test was applied to compare bat exclusion treatment with each other, it was found that there was a significantly different between this treatment and bird exclusion (p = 0.046), and control (0.015) but not for both exclusion treatment (p=0.085)

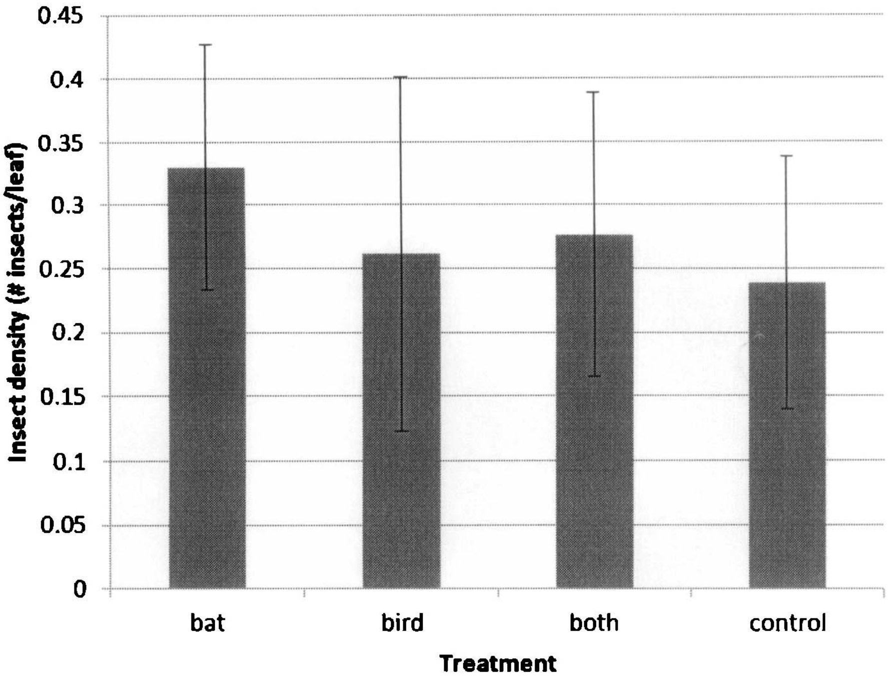

Figure 1 Mean insect density in each leave based on an average of 165 observed leaves per tree from 18 trees in each treatment.

<u>Bird activity</u>

More than 223 individuals of 50 species of bird observed over 16 observation period. All but one bird observation carried out in the morning. From 223 individuals seen in the orchard, the most abundance ones are Common tailor bird, Sunbird, Asian brown flycatcher, Warbler, Orange bellied flowerpecker, Puff-throated babbler, Common iora (table 1)

<u>Bat activity</u>

18 full night sampling with Anabat revealed 673 bat echolocation files. At least 12 insectivorous bat species were tentatively identified. Quantitatively, *Myotis muricola* (Vespertilionidae, 65%) and *Rhinolophus affinis* (Rhinolophidae, 23.5%) contributed for 88% of all recorded files. The other species found with Anabat were *R. malayanus*, *Myotis* sp., *Hipposideros armiger*, *R. robinsoni*, *R. trifoliatus*, *H. diadema*, *R. lepidus*, *R. stheno*, *Emballonura monticola*, *Myotis cf. horsefieldi* (table 2).

DISCUSSION

Insectivores provide an important service in regulating insect populations, which may otherwise become crop pests. Their assistance is particularly valuable in agricultural settings, where reduced plant species diversity often provide abundant and easy food resources to herbivorous insects. Yet most studies have focused on diurnal insectivores, without considering the effect that nocturnal insectivores may have on arthropod communities.

Thus, the intent of our study was to parcel out the relative impacts of bats and birds on arthropod density in an agricultural setting. Our results did show that treatment had a significant effect on the arthropod community. Bat showed the strongest role in insect control and followed by bird. We hypothesized that the both-excluded trees would have the highest arthropod densities, as the netting would prevent bats and birds from gleaning arthropods off of them, was not supported. However, our hypothesis that the control trees would have the lowest arthropod densities, as the lack of netting would allow bats and birds to forage among the foliage was suuported.

There are several factors that may have contributed to this finding. Perhaps the most considerable influence was the presence of spiders on the netting. The mesh netting provided excellent substrate for spider webs, which were not included in arthropod surveys, as only individuals found on the tree itself were counted. Trees which excluded both bats and birds were particularly impacted; because the exclosures on these trees were never disturbed, the webs were able to accumulate. Conversely the netting on bat- and bird-excluded trees were disturbed twice a day, disrupting any existing webs. The extensive spider webs on the both-excluded trees likely played a substantial role in reducing arthropod density.

Two aspects regarding our arthropod sampling procedure may have also had a confounding effect. First of all, censuses were always conducted during the day, meaning that nocturnal arthropods are possibly underrepresented in our study. Therefore, the influence of bats in controlling arthropod densities is potentially underestimated, as they likely have a larger effect on the nocturnal arthropod community. Additionally, no attempt was made to distinguish between herbivorous and predacious arthropods. While the control trees had highest arthropod densities, this may not necessarily correspond to the highest herbivory rates, depending on the ratio of arthropods that eat plant material to arthropods that eat other arthropods. Future studies should consider a representative and practical method of measuring herbivory, which may be a more useful indicator of insectivore control of *pest* arthropod abundance.

A couple of properties inherent to our study system may have influenced our results as well. Our study was conducted, not in an agricultural monoculture, but in a mixed fruit orchard with abundant native shrubbery and other vegetation. Crop heterogeneity has been shown to reduce the amount of damage caused by pests. Thus, conducting a similar experiment in a monoculture may yield a greater treatment effect. Furthermore, we were limited to testing relatively small trees. Young trees may naturally have fewer arthropods. For example, arthropods possibly avoid such trees, as the spare foliage may not provide sufficient concealment. Their lack of fruit also reduces the likelihood of encountering frugivorous insects. Additionally, arthropods – particularly generalists – may avoid immature trees since plants typically invest more chemical defenses in vulnerable new leaves. If arthropod densities are already low on immature trees, excluding bats and birds may not have a dramatic effect. This possibility could be studied by comparing the relative effects of insectivore exclusions on immature versus mature plants.

Yet, in general, bats and birds help protect longkong from herbivorous insects. The major pests of longkong are bark borers, which evade bat and bird predation by burrowing inside the branches and trunk. The fact that other folivorous insects are not considered pests suggests that insectivores help keep such population numbers in check.

The results of our study yielded important findings. Additionally, the discovery of a number of unanticipated confounding factors (the impact of spider webs, the censusing procedure, and the structure of our study system) will facilitate future studies in constructing stronger methodologies. As the ecosystem services provided by insectivores generate immense monetary and temporal savings, additional research in this field will be greatly beneficial. In particular, parsing out the separate impacts of bats and birds on arthropod abundance, and any interaction between the two insectivore groups, will improve our understanding of this valuable service.

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Table 1 birds observed at understory and canopy of trees in fruit orchard.

Common name	Number observed
common tailorbird	25
sunbird sp.	23
asian brown flycatcher	16
warbler sp.	14
orange-bellied flowerpecker	10
several sp (mostly flowerpecker)	10
swift sp.	10
common iora	9
puff-throated babbler	9
leaf-warbler sp., flowerpecker sp.	8
flowerpecker sp.	6
Unknown	6
white-eye sp.	6
leaf-warbler sp.	5

olive-backed sunbird, common tailorbird, ruby-cheeked sunbird	5
spiderhunter sp.	5
tree babbler sp.	5
blue-throated flycatcher	4
Abbott's babbler	3
green-billed malkohoa	3
plaintive cuckoo	3
ruby-cheeked sunbird	3
babbler sp.	2
brown shrike	2
brown-throated sunbird	2
dark-necked tailorbird	2
leafbird sp.	2
maroon woodpecker	2
oriental magpie robin	2
scarlet-backed flowerpecker	2
brown-streaked flycatcher	1
common wood-shrike	1
copper-throated sunbird	1
flycatcher sp.	1
blue-throated flycatcher	1
iora sp.	1
large wood-shrike	1
leaf warbler sp.	1
little spiderhunter	1
mountain tailorbird	1
pied triller	1
plain sunbird	1
rufous-tailed tailorbird	1
streak-earred bulbul	1
thick-billed flowerpecker	1
white-rumped munia	1
wren sp.	1
yellow wagtail	1
yellow-vented flowerpecker	1

Table 2 bat species tentatively identified from Anabat recording stations

Bat species	Number of recorded files
Myotis muricola	438
Rhinolophus affinis	158
R. malayanus	19
Myotis sp.1	15
Hipposideros armiger	11
R. robinsoni	9
H. diadema	7
R. trifoliatus	7
R. lepidus	4
Emballonura monticola	2
R. stheno	2
Myotis cf. horsefiedi	1
	673

Alyssa is counting the insect on leaves of longong in the mixed fruit orchard.