Diet, Home Range and Habitat Use Effects on the Seed Dispersal of a Pioneer Tree by Two Bulbul Species

Thanate Kerdkaew

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Author	Mr. Thanate Kerdkaew
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Major Advisor :	**Examining Committee :**
…………………………………......	..…..…...…………………..…Chairperson
(Asst. Prof. Dr. Sara Bumrungsri)	(Asst. Prof. Dr. Vijak Chimchome)
	..….....……………………….……………..
Co-advisor :	(Asst. Prof. Dr. Sara Bumrungsri)
……………………………………	..….....…………………………………...
(Assoc. Prof. Dr. George A. Gale)	(Assoc. Prof. Dr. George A. Gale)
	..…..………………………………………
	(Assoc. Prof. Suparoek Watanasit)
	..…..………………………………………
	(Dr. Prakart Sawangchote)

The Graduate School, Prince of Songkla University, has approved this thesis as partial fulfillment of the requirements for the Master of Science Degree in Ecology (International Program)

……………………………….....…
(Assoc. Prof. Dr. Teerapol Srichana)
Dean of Graduate School

This is to certify that the work here submitted is the result of the candidate's own investigations. Due acknowledgement has been made of any assistance received.

………………………………… Signature

(Asst. Prof. Dr. Sara Bumrungsri)

Major Advisor

………………………………… Signature

(Mr. Thanate Kerdkaew)

Candidate

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……………………………….....Signature

(Mr. Thanate Kerdkaew)

Candidate

ชื่อวิทยานิพนธ์ อาหาร, ขนาดและการใช้พื้นที่อาศัยส่งผลต่อการกระจายเมล็ดพันธุ์ของพืชเบิกนำโดยนกปรอดสองชนิด

ชื่อผู้เขียน นายธเณศ เกิดแก้ว

สาขาวิชา นิเวศวิทยา (นานาชาติ)

ปีการศึกษา 2556

บทคัดย่อ

พื้นที่ที่อยู่ระหว่างการเปลี่ยนแปลงแทนที่ขั้นเริ่มต้นเป็นพื้นที่เปิดโล่ง ซึ่งส่วนใหญ่แล้วจะปกคลุมด้วยหญ้า วัชพืช และพรรณไม้เบิกนำ ในพื้นที่ศึกษานี้พืชเบิกนำชนิด *Callicarpa arborea* (Lamiaceae) และ *Melastoma malabathricum* (Melastomataceae) มีความชุกชุมสูงและเป็นพืชหลัก ซึ่งพืชเหล่านี้มีความเป็นไปได้สูงว่าจะเป็นแหล่งอาหารสำคัญของนกที่อาศัยอยู่ในบริเวณนี้ นกกลุ่มปรอด (Family : Pycnonotidae) ซึ่งเป็นนกที่กินทั้งผลไม้และแมลง เป็นนกที่พบได้บ่อยสุดในพื้นที่ศึกษา โดยเฉพาะอย่างยิ่งนกปรอดสีน้ำตาลตาแดง (*Pycnonotus brunneus*) และนกปรอดหน้านวล (*Pycnonotus goiavier*) โดยนกปรอดเหล่านี้อาจเป็นผู้กระจายเมล็ดพันธุ์หลักของพืชเบิกนำในบริเวณนี้เนื่องจากมีความชุกชุมที่สูง ในการศึกษานี้มีเป้าหมายที่จะตอบข้อสงสัยในเรื่องขององค์ประกอบอาหาร ขนาดพื้นที่และชนิดของพื้นที่อาศัยของนกปรอดสีน้ำตาลตาแดงและนกปรอดหน้านวล รวมถึงประสิทธิภาพในการเป็นผู้กระจายเมล็ดพันธุ์ของพืชเบิกนำท้องถิ่นชนิด *Callicarpa arborea* ซึ่งเกี่ยวข้องกับปริมาณการกินผลไม้ ระยะทางการกระจายเมล็ดพันธุ์ และรูปแบบพื้นที่ที่เมล็ดพันธุ์เหล่านั้นมีโอกาสไปตก ในการศึกษาเรื่ององค์ประกอบของอาหารพบว่านกปรอดทั้งสองชนิดกินผลไม้เป็นหลัก โดยคิดจากเปอร์เซ็นค่าความสำคัญ (%IV) ได้มากกว่า 95% นอกจากนี้ยังพบว่านกปรอดสีน้ำตาลตาแดงกินผลของพืชอย่างน้อย 13 ชนิด ในขณะที่นกปรอดหน้านวลพบ 10 ชนิด นกปรอดทั้งสองชนิดกินผลของพืชเบิกนำ *Callicarpa arborea* เป็นหลักโดยคิดเป็น 62.82% ของอาหารทั้งหมดในนกปรอดสีน้ำตาลตาแดง และคิดเป็น 65.98% ในนกปรอดหน้านวล จากการศึกษาส่วนนี้ได้พบสิ่งที่น่าสนใจคือ นกปรอดทั้งสองชนิดได้กินผลของโคลงเคลงขนต่อม (*Clidemia hirta*, Family : Melastomataceae) ซึ่งเป็นพืชต่างถิ่นในปริมาณ 24.66% ของอาหารทั้งหมดในนกปรอดสีน้ำตาลตาแดง และ 3.10% ในนกปรอดหน้านวล จากการศึกษาองค์ประกอบของอาหารสามารถสรุปได้ว่า นกทั้งสองชนิดสามารถเป็นผู้ช่วยกระจายเมล็ดพันธุ์ทั้งของพืชท้องถิ่นและพืชต่างถิ่น ในส่วนต่อมาได้ทำการศึกษาขนาดและการใช้พื้นที่อาศัยของนกปรอดทั้งสองชนิดพบว่า ค่าเฉลี่ยของพื้นที่อาศัยแบบ 95% Minimum Convex Polygon ของนก

ปรอดสีน้ำตาลตาแดงมีค่าเท่ากับ 7.09 ± 4.89 เฮกตาร์ มีขนาดใหญ่กว่าอย่างมีนัยสำคัญเมื่อเปรียบเทียบกับของนกปรอดหน้านวล ซึ่งมีขนาดเพียง 2.68 ± 1.60 เฮกตาร์ ส่วนของค่าเฉลี่ยขนาดของ core area (50% MCP) ของนกปรอดสีน้ำตาลตาแดงมีค่าเท่ากับ 1.39 ± 1.06 เฮกตาร์ ซึ่งมีขนาดใหญ่กว่าอย่างมีนัยสำคัญเมื่อเปรียบเทียบกับของนกปรอดหน้านวล ซึ่งมีขนาดเพียง 0.46 ± 0.15 เฮกตาร์ นอกจากนี้นกทั้งสองชนิดมีการเลือกใช้พื้นที่อาศัยแบบไม่สุ่ม นกปรอดสีน้ำตาลตาแดงเลือกใช้พื้นที่ขอบป่าในปริมาณเท่ากับป่าด้านใน ซึ่งมากกว่าการใช้พื้นที่ทุ่งหญ้าเปิดโล่ง สวนปาล์มน้ำมัน และสวนยางพาราตามลำดับ ซึ่งแตกต่างจากนกปรอดหน้านวลที่ใช้พื้นที่ทุ่งหญ้าเปิดโล่งเป็นพื้นที่อาศัยหลัก ซึ่งมากกว่าการใช้พื้นที่สวนปาล์มน้ำมัน ขอบป่า และสวนยางพาราตามลำดับ โดยพื้นที่ทั้งสามชนิดนี้นกปรอดหน้านวลเข้าไปใช้ในปริมาณที่น้อยมากๆ ในส่วนสุดท้ายเป็นการศึกษาถึงประสิทธิภาพในการเป็นผู้กระจายเมล็ดพันธุ์ของนกปรอดทั้งสองชนิดของพืชเบิกนำ *Callicarpa arborea* จากการศึกษาพบว่านกปรอดทั้งสองชนิดเป็นผู้มาเยือนและเป็นผู้กินผลหลักของพืชชนิดนี้ ในแง่ของการเป็นผู้กระจายเมล็ดพันธุ์พืชเชิงปริมาณ นกปรอดหน้านวลสามารถทำได้ดีกว่า เนื่องจากมีอัตราการกินผลที่สูงคิดเป็นปริมาณ 4.4 ± 4.83 ผลต่อชั่วโมง ซึ่งสูงกว่าของนกปรอดสีน้ำตาลตาแดงอย่างมีนัยสำคัญ โดยมีอัตราการกินผลเพียง 1.9 ± 2.53 ผลต่อชั่วโมง อย่างไรก็ดี พฤติกรรมอื่นๆของนกปรอดทั้งสองชนิดที่พบบนต้น *Callicarpa arborea* นั้นไม่ต่างกัน ผลของพืชชนิดนี้ถูกกินโดยนกทั้งสองชนิดในช่วงเวลาเช้า (0700h – 0930h) และช่วงเวลาบ่ายแก่ (1430h – 1700h) เป็นหลัก นอกจากนี้คะแนนชีพลักษณ์ของปริมาณผลสุกของพืชชนิดนี้มีความสัมพันธ์ในเชิงบวกต่อค่าเฉลี่ยของจำนวนผลไม้ที่ถูกกินต่อชั่วโมงโดยนกปรอดทั้งสองชนิด ซึ่งหมายความว่ายิ่งปริมาณผลสุกมากเท่าไรอัตราการกินผลไม้โดยนกทั้งสองชนิดนี้ยิ่งมากตามไปด้วย นกปรอดทั้งสองชนิดมีระยะเวลาที่อาหารผ่านทางเดินอาหารที่ไม่แตกต่างกัน และเมล็ดพืชทั้งหมดที่กินเข้าไปจะถูกขับถ่ายออกมาภายใน 1 ชั่วโมงหลังจากกินเข้าไป นอกจากนี้นกปรอดทั้งสองชนิดสามารถนำพาเมล็ดของต้น *Callicarpa arborea* มากกว่า 90%ไปไกลจากต้นแม่ อย่างไรก็ดีนกปรอดทั้งสองชนิดมีความแตกต่างกันของการนำพาเมล็ดของพืชชนิดนี้ไปสู่ในพื้นที่ที่เหมาะสมต่อการงอก ในนกปรอดสีน้ำตาลตาแดงเมล็ดส่วนใหญ่จะถูกนำไปในเขตขอบป่าซึ่งคิดเป็น 55.01% ขณะที่นกปรอดหน้านวลจะนำพาเมล็ดเกือบทั้งหมดคิดเป็น 97.49% ไปตกในเขตพื้นที่ทุ่งหญ้าเปิดโล่ง ในกรณีนี้สามารถอนุมานได้ว่าพื้นที่ทุ่งหญ้าเปิดโล่งเป็นพื้นที่เหมาะสมต่อการงอกของ *Callicarpa arborea* เนื่องจากพืชชนิดนี้ชอบพื้นที่โล่ง ดังนั้นอาจสรุปได้ว่า นกปรอดหน้านวลมีแนวโน้มที่จะเป็นผู้กระจายเมล็ดพันธุ์ที่มีคุณภาพมากกว่านกปรอดสีน้ำตาลตาแดง

Thesis Title Diet, Home Range and Habitat Use Effects on the Seed Dispersal of a Pioneer Tree by Two Bulbul Species

Author Mr. Thanate Kerdkaew

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ABSTRACT

Early successional habitat is an open area which fully covered by grasses, weeds and pioneer plants. Some pioneer plants, such as, *Callicarpa arborea* (Lamiaceae) and *Melastoma malabathricum* (Melastomataceae), are high abundant and may be an important food resource for birds living in this area. Bulbuls (Family : Pycnonotidae), a frugivorous-insectivous bird, is the major group commonly found in this area, especially, red-eyed bulbul, *Pycnonotus brunneus*, and yellow-vented bulbul, *Pycnonotus goiavier*, and it may be the important seed dispersal agents of pioneer plants because of its high abundant. In this study, I aim to examine the diet, home range size and habitat use of two common bulbuls, red-eyed bulbul and yellow-vented bulbul, and their seed dispersal effectiveness of pioneer tree, *Callicarpa arborea* in term of fruit removal, dispersal distance and seed site deposition. For diet study, both bulbuls were highly frugivorous which more than 95% of diet is plant, based on important value percent (%IV). It is found that red-eyed bulbul fed on at least 13 plant species, and minimum 10 plant species were fed by yellow-vented bulbul. Moreover, it has been suggested that both bulbuls majority fed on a native pioneer tree, *Callicarpa arborea*. This plant accounted for 62.82% and 65.98% of red-eyed bulbul and yellow-vented bulbul overall diet respectively. Interestingly, both bulbuls included one alien plant, *Clidemia hirta* (Melastomataceae), in their diet which comprising 24.66% of red-eyed bulbul diet and 3.10% of yellow-vented bulbul diet. It can be concluded that not only native but also exotic plant can be dispersed by both bulbuls. In home range and habitat use study, The mean 95% Minimum Convex Polygon home range size of red-eyed bulbul (7.09 ± 4.89 ha.) was significantly larger than of yellow-vented bulbul (2.68 ± 1.60 ha.). In addition, the mean core area size (50% MCP) of red-eyed bulbul (1.39 ± 1.06 ha.) was significantly larger than of yellow-vented bulbul (0.46 ± 0.15 ha.). Moreover, both birds showed non random habitat selection. Red-eyed bulbul tended to used transition zone equally to forest interior, but higher than using open grassland, oil palm plantation and rubber plantation respectively. However, yellow-vented bulbul almost selected open grassland as its main habitat, which drastically higher than using oil palm plantation, transition zone and rubber plantation respectively. In seed dispersal effectiveness study, both bulbuls were the main visitor and contributed highest fruit removal. However, It is suggested that yellow-vented bulbul had better seed dispersal quantity of *C. arborea* as it could remove 4.4 ± 4.83 fruits/hour which significantly higher than of red-eyed bulbul (1.9 ± 2.53 fruits/hour). However, other behaviours on *C. arborea* of both bulbuls were similar. Moreover, fruits were mostly removed in the morning (0700h – 0930h) and late afternoon (1430h – 1700h). Ripe fruit phase score correlated positively mean fruit removal/hr, suggesting that the more fruits on tree the more fruits removed. In addition, mean gut retention time of both bulbuls was not significantly different. All seeds dropped after feeding on fruits around 1 hour. It is suggested that the majority of seeds around 90% were dispersed far from parent tree by both bulbuls. It is noticeable that the seed site deposition was different among bulbul species. In red-eyed bulbul, most seeds were defecated in transition zone (55.01%). However, 97.49% of seeds carried by yellow-vented bulbul were dropped in open grassland. Because *C. arborea* is found only in an open area, it is assumed that open grassland is a suitable habitat for *C. arborea* seed. It can be concluded that yellow-vented bulbul is higher effective seed disperser of *C. arborea* than red-eyed bulbul as it dispersed seeds to more suitable area.

CONTENTS

SUMMARY OF CONTENTS

1.1 INTRODUCTION

Khao Pra Bang Khram Wildlife Sanctuary, Krabi province, is the one area in southern Thailand facing deforestation which a great number of forest areas were converted illegally to oil palm and rubber plantation (Maxwell, 2009). The forest area here is described as a lowland sundaic forest (Barber *et al.*, 2011), and it is the only one habitat that the endangered bird, Gurney's Pitta, *Pitta gurneyi*, can be found in Thailand (Maxwell, 2009 ; Barber *et al.*, 2011). After illegal use, some of those lands were abandoned for a while, and they have been changing through time to be an early successional habitat. In the early succession area, almost area is open, mostly covered by Congon grass (*Imperata cylindrica*), Melastoma shrub, *Melastoma malabathricum*, and pioneer trees, for example, *Callicarpa arborea*, *Antidesma ghaesembilla*, and *Ficus hispida* (Maxwell, 2009). *C. arborea* is the most common tree in this area (Kerdkaew, unpublished), and it produces numerous ornithochoric fruits throughout the year (Leeratiwong *et al.*, 2009). It may attract many frugivorous birds to feed on its fruits, and these birds can disperse seeds for this plant which may lead to the dynamic of vegetation. In this area, bulbuls (Family : Pycnonotidae) were reported as the common bird family found here (Round and Brockelman, 1998), and they contributed for the highest visit on the pioneer tree, *C. arborea* (Sritongchuay *et al.*, submitted). Moreover, red-eyed bulbul (*Pycnonotus brunneus*) and yellow-vented bulbul (*P. goiavier*) were the species that frequently found in this area (Kerdkaew, pers. obs.). Bulbuls are known for their important role in seed dispersal in oriental region, especially in degraded habitat (Corlett, 1998; Weir and Corlett, 2007) as they are a generalist frugivore which is more flexible to feed on many plant species (Wang *et al.*, 2005 ; Sankamethawee *et al.*, 2011). Bulbuls can be an effective seed dispersal since they remove fruits, swallow them, and move away from tree they feed on to defecate at somewhere that far away (Corlett, 2002). Although the previous study suggested that bulbuls may be important seed dispersal here. Seed dispersal study in this area is still limited. The only one research has done on the seed rain under different microhabitat (Sritongchuay *et al.*, submitted) which provided only the quantitative analysis of seed number fall to ground without any data described on other aspects in seed dispersal. Hence this study investigates on the role of the two common species of bulbuls (*P. bruneus* and *P. goiavier*) on the seed dispersal of the common pioneer plant (*C. arborea*). We concern on some behavior of this two bulbuls, such as, diet, home range and habitat use which may contribute to the different in seed dispersal. Also, we observed the frugivore assemblage, focused on the two species that are the most common, in term of visitation rate, fruit removal, time spent on *C. arborea* tree which accounting for seed dispersal quantity provided by them. The qualitative seed dispersal, for example, seed dispersal distance and seed site deposition, is also studied. This study will provide a clearer image of seed dispersal in this area.

1.2 PROJECT OBJECTIVES

The purposes of this study are to

1) account for diet of *Pycnonotus bruneus* and *P. goiavier* in an early successional habitat,

2) examine home range size and habitat use of *P. bruneus* and *P. goiavier*,

3) determine and compare seed dispersal quantity in term of fruit removal and quanlity in term of seed dispersal distances and seed site deposition provided by *P. bruneus* and *P. goiavier* of a pioneer tree, *C. arborea*.

1.3 RESULTS AND DISCUSSIONS

From November 2011 to October 2012, 35 and 31 faeces from *Pycnonotus brunneus* and *P. goiavier* were collected for diet analysis by mist netting, respectively. Based on important value percentage (%IV), both birds were highly frugivorous as more than 95% of diet was plants. *P. brunneus* and *P. goiavier* fed on at least 13 and 10 plant species, respectively. The majority diet of these bulbuls was *Callicarpa arborea* which found in *P. brunnues* and *P. goiavier* diet by 62.82% and

65.98% respectively. Surprisingly, the introduced shrub, *Clidemia hirta*, was included in diet composition by 24.66% of *P. brunneus* and by 3.10% of *P. goiavier*. Clearly, it has been suggested that the diet of these bulbuls in an early successional habitat was *C. arborea* fruits**.** This study is the first report that emphasize on the native bulbuls feeding on the exotic Clidemia which possibly relates to seed dispersal of *C. hirta* in this area (Kerdkaew *et al*., 2014a).

Additionally, we applied radiotelemetry method to investigate the home range size and habitat use of *Pycnonotus brunneus* and *P. goiavier* between December 2011 to October 2012. 13 and 10 individuals of *P. brunneus* and *P. goiavier* were followed for 4-8 tracking days. The 95% MCP home range size of them were drawn and compared among species. The overall habitat uses of these birds were separately analyzed by the compositional analysis for each species. For *P. brunneus*, home range size was between 2.20 and 19.07 ha, and mean home range size was 7.09 ± 4.89 ha. Home range size increased significantly with the hour of observation ($r = 0.906$, $P = 0.002$), and also this bird was likely nomadic at some point which affect the increase of home range size. The mean core area size (50% MCP) of red-eyed bulbul (1.39 ± 1.06 ha.) was significantly larger than of yellow-vented bulbul (0.46 ± 0.15 ha.). The habitat use of *P. brunneus* was nonrandom selection ($\lambda = 0.012$, $P < 0.001$). The summarization of habitat use was "transition zone = forest interior > open grassland >>> oil palm plantation > rubber plantation". For *P. goiavier*, the home range sizes ranged from 1.42 to 6.69 ha, and mean home range size was 2.68 ± 1.60 ha. We found that the mean home range size of *P. brunnues* was bigger than of *P. goiavier* ($t = 3.650$, $df = 21$, $P = 0.001$). Although home range size tended to increase by the hour of observation ($r = 0.940$, $P = 0.001$), the home range size of *P. goiavier* is not likely to increase as it is a sedentary species. *P. goiavier* presented non random habitat selection ($\lambda = 0.02$, $P < 0.001$) and almost used open grassland. The overall habitat use of this bird was "grassland >>> oil palm plantation = transition zone > rubber plantation". It is suggested that the home range size and habitat use of these two bulbul species were different. It may relate to other factors, such as, sex, following fruit production, breeding status or group size (Kerdkaew *et al*., 2014b).

Moreover, we investigated on the seed dispersal quantity and quality of a pioneer tree, *Callicarpa arborea*, by red-eyed bulbul (*Pycnonotus brunneus*) and yellow-vented bulbul (*P. goiavier*). Average fruit removal/hr. of *P. goiavier* (4.4 ± 4.83 fruits/hour) was significantly higher than of *P. brunneus* (1.9 ± 2.53 fruits/hour) (Mann-Whitney U-test: U = 595.5, P = 0.002). Clearly, *P. goiavier* was higher quantity seed dispersal. The other behavior of these bulbuls observed on *C. arborea* trees, such as, mean feeding time and number of fruit removed/visit, were not statistically different. The majority of fruits were removed in the morning and late afternoon by both bulbuls. In addition, ripe fruit phase score increase by mean fruit removal/hr (*P. brunneus*; r_s = 0.579, P = 0.024, *P. goiavier*; r_s = 0.595, P = 0.021), but the ripe fruit phase score did not correlate with mean time spent on *C. arborea* tree. These two bulbuls had similar mean gut passage time which may be explained by their similar body size (24-37 g). All seeds were defecated within 1 hr after fruits ingestion. We found that both bulbuls dispersed more than 90% of seeds far from parent tree. However, the site deposition of seed was noticeably different. In *P. brunneus*, the majority of seeds, 55.01%, were defecated in transition zone, whereas, in *P. goiavier*, seeds were almost dropped in grassland by 97.49%. *C. arborea* is a pioneer plant which only found establish in open grassland, also its shoots. It can be argued that *P. goiavier* was likely to be a high quality seed disperser of this plant as most seeds were dispersed in grassland. Factor affecting seed dispersal effectiveness may be occurred by different habitat use by both bulbuls. It can be concluded that *P. goiavier* is higher effective seed disperser of *C. arborea* than *P. brunneus* (Kerdkaew *et al*., 2014c).

1.4 CONCLUDING REMARKS

Based on diet studies, both bulbuls fed on many plant species and they may be an important seed disperser in an early successional area. Not only native plants but also exotic plant, *Clidemia hirta*, could be dispersed in the study area by both bulbuls. The home range size of red-eyed bulbul, *Pycnonotus brunneus*, was significantly larger than that of yellow-vented bulbul, *P. goiavier*. Moreover, the habitat uses of these birds were different. *P. brunneus* frequently selected dense vegetation areas, in this case, transition zone and forest interior, whereas *P. goiavier* almost used open grassland as its main habitat. In addition, the comparison of seed dispersal effectiveness of a pioneer tree, *Callicarpa arborea*, provided by these two bulbul species emphasized that *P. goiavier* had higher seed dispersal effectiveness of than that of *P. brunneus* because P. goiavier showed higher in both quantity and quality seed dispersal so that this bulbul was likely to be an important seed dispersal agent of *C. arborea*.

1.5 RECOMMENDATIONS FOR FURTHER STUDIES

Even though this study provided a lot of information on diet, ranging behavior and role of red-eyed bulbul, *Pycnonotus brunneus*, and yellow-vented bulbul, *P. goiavier* in seed dispersal of pioneer tree, more intensive studies are needed to complete gap of study in some aspects.

In diet study, as the number of sample size was too low for generalizing diet of our studied bulbuls, it is likely that the dataset of diet analysis is too preliminary. Moreover, diet of these bulbuls can be fluctuated by fruit productivity and season, for example, in breeding season. During breeding season bulbuls could increase animal, particularly insect, for obtaining more protein and calcium which use for producing eggs. Therefore, further works must have more sample size of bird faeces from different seasons and fruit productivity periods for better accuracy and precision of diet analysis.

Although diet analysis in this study dealt with small sample size, at least it revealed an interesting fact that these bulbuls included the exotic plant, *Clidemia hirta*, to their diet. It means that bulbuls can be a seed dispersal agent of this plant in southern Thailand. To date it is not clear about invasive status of this plant in Thailand, but it was reported as a serious invader in Malaysia (Peters, 2001) and Singapore (Teo et al., 2003). Therefore, further work should focus on the *C. hirta* and frugivore interaction, and how it affects ecosystem in Thailand.

In home ranges and habitat uses study, all birds were tracked for a short period (3-8 days). It is suggested that if tracking time is extended, the home range size of both birds may increase. Also, with longer tracking period, the habitat use may alter. Moreover, the effect of season (breeding, fruiting), sex, group size, social behavior may affect home range size and habitat use so that further study is needed to investigate in more detail about these factors by tracking more bird individuals which actually relates to them. In addition, in this study we could not describe the home range overlap for both species as we did not track a lot of individual at the same time, so increase sample size of bird number tracked in same period would fulfill this gap.

This work is only the preliminary study to understand the process of seed dispersal in southern Thailand. Furthermore, it is reported that Thailand has more than 1,000 species of birds indicating that we have powerful study site for many aspects of ecology. By the high bird biodiversity, the birds' seed dispersal study still needs to investigate. However, there are few studies that concerned on seed dispersal in Thailand, and only some works have done in evergreen forest at Khao Yai National Park which mostly focused on Hornbills (Poonswad *et al*., 1998a ; Poonswad *et al*., 1998b ; Kitamura *et al*., 2004a ; Kitamura *et al*., 2004b ; Kitamura *et al*., 2004c ; Kitamura *et al*., 2006), and puff-throated bulbul, *Alophoixus pallidus* (Khamcha, 2009). Also, there are some researches done on the wider scope of seed dispersal which focusing on plant-frugivore interactions (Kitamura *et al*., 2002 ; Kitamura *et al*., 2005a ; Kitamura *et al*., 2005b ; Sankamethawee *et al*., 2011). However, in southern Thailand, to date, there is only one research focusing on seed rain study in lowland tropical habitat (Sritongchuay *et al*., in press), and this work which examine the role of seed dispersal in term of effectiveness by bubuls only so that further studies should examine on seed dispersal of other plants by other frugivores in other habitat types. Additionally, seed dispersal effectiveness, especially, qualitative seed dispersal, deals with other studies, such as, gut treatment, seed germination and seedlings establishment so these studies remain necessary to describe seed dispersal quality to be more completed. Moreover, other aspects of seed dispersal study, such as, seed predation, secondary seed dispersal, or other scopes in seed fate are necessary to investigate. In southern Thailand, many natural habitats have been dominating by human activities and lead to the habitat degradation. To restore those habitats, the data on seed dispersal and plant-frugivore interaction should be collected as this information is the knowledge base which can provide the whole image of habitat dynamic and benefit for long term biological conservation.

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Short Note

Preliminary Diet Analysis Reveals the Dispersal of an Exotic Plant by Two Native Bulbuls in an Early Successional Habitat, Krabi, Southern Thailand

THANATE KERDKAEW[1*], GEORGE ANDREW GALE[2] AND SARA BUMRUNGSRI[1]

[1]*Small Mammals and Birds Research Unit, Department of Biology, Faculty of Science, Prince of Songkla University, Songkhla, 90112, THAILAND*
[2]*Conservation Ecology Program, School of Bioresources and Technology, King Mongkut's University of Technology Thonburi, Bangkhuntien, Bangkok, 10150, THAILAND*
* Corresponding Author: Thanate Kerdkaew (kerdkaew.t@gmail.com)
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Frugivorous birds play a dominant role in mutualisms with plants as seed dispersers in the tropics[1,2]. The potential role of birds in seed dispersal can be investigated directly through diet studies [3-5]. Bulbuls (Family Pycnonotidae), are well known as generalist frugivores which feed on fruits of numerous plant species[3,6-9], and they are possibly the most important small-bodied seed dispersal agents in the Oriental region[1]. Furthermore, in the few regional studies available, bulbuls have been shown to be numerically dominant as visitors to fruiting plants in both primary[9] and successional habitats[10]. However, studies of seed dispersal by bulbuls are still few and investigations of diet of these bulbuls could provide valuable additional information on the role of bulbuls as seed dispersers.

Of particular interest is the role of dispersers such as bulbuls in the dispersal of exotic, invasive species[4,11]. The introduced shrub, *Clidemia hirta* for example has the potential to be dispersed by bulbuls given the plant's ecology. It is a shade tolerant, under-storey species, which can be found in disturbed habitats, agricultural areas and along roadsides[12]. This plant has the ability to compete with native shrubs, and it is reported globally as an invasive species in the tropics[13]. *Cl. hirta* produces numerous berry fruits which can attract both native[14] and exotic frugivores[4,15]. It has been suggested that, possibly, the invasive *Clidemia* was mainly dispersed on the Silhouette Island, Republic of Seychelles by the indigenous bulbul, *Hypsipetes crassirostris*[14]. Thus, due to its ornitochoric fruit production and aggregated population, it is highly likely that native bulbuls in early successional areas of South-East Asia could include the introduced *Clidemia* in their diet. However, to date, there are no official reports of how this plant interacts with native frugivores in this region.

Red-eyed bulbul (*Pycnonotus brunneus* Blyth, 1845) and yellow-vented bulbul (*Pycnonotus goiavier* Scopoli, 1786) are common birds found in early successional areas. They have similar body sizes which range from 24 to 37 g[8]. Although these birds are widely distributed in Southern Thailand, only *P. goiavier* can be found in central Thailand having a considerably wider distribution range than *P. brunneus*[8]. The aim of our study was to examine the diet of *P. brunneus* and *P. goiavier* in an early successional habitat and to quantify the composition of both native and introduced plants in their diets.

The study was conducted in the Khao Pra Bang Khram Wildlife Sanctuary, located in Krabi Province, southern Thailand (8°10' N, 98°80' E). The study site is approximately 20 hectares and is surrounded by continuous forest. There is a small stream which runs across the middle of the study site, although it remained dry from the end of February to the end of March 2012. The climate is classified as tropical wet seasonal[16] with an annual precipitation ca. 2,905 mm in the year of study (November 2011 to October 2012). The majority of rainfall (61.0%) occurred from mid April to October (rainy season) while less rain fell during November to March (39.0 %). The average minimum temperature was lowest in August and September (19.5°C) and peaked in April (20.8°C). The average maximum temperature was highest in February (33.5°C), and it was lowest in December (31.0°C). Majority of vegetation within the sanctuary, is lowland (25-100 m asl) tropical forest consisting of primary evergreen or seasonal forest, and mixed floras of hardwoods and bamboos[17]. This protected area is mostly surrounded by oil palm and rubber plantations, and small remaining forest patches. The study site consists of patches of grassland mixed with secondary growth in the protected area. Previously, the study area had been used illegally as cropland, and it was abandoned after establishment of the protected area approximately 25 years ago. The patches of grassland consist of a variety of weeds and grasses (e.g. *Ageratum conyzoides* L., *Imperata cylindrica* (L.) P. Beauv. var. major (Nees) C.E. Hubb. ex Hubb. &Vaugh. and *Eupatorium odoratum* L.), woody species (e.g. *Melastoma malabathricum* L. ssp. *malabathricum*). The pioneer tree species, *Callicarpa arborea* Roxb. var. *arborea*, is commonly interspersed in this grassland[17].

Pycnonotus brunneus and *P. goiavier* were captured with mist nets (2.5 x 9 m^2) in the study site two days per month from November 2011 to October 2012. During each trapping day, six mist nets were set adjacent to bird feeding routes near the forest edge, the center of grassy areas and near the stream where many bird species used for bathing. Mist nets were placed in these sites from 0700h to 1700h, with a total trapping effort of 1,440 net-hours. Mist nets were closed temporarily during strong winds or rain. All deployed mist nets were monitored every ten minutes to check if there were any birds trapped. If *P. brunneus* and *P. goiavier* were trapped, they were individually put in cloth bags (10 x 20 cm^2) for 30-45 minutes, longer than the mean gut passage time of these bulbuls (23 minutes) (T. Kerdkaew, unpubl. data) to ensure that birds would defecate. All faeces were kept in 1.5 ml Eppendorf tubes and preserved with 70% ethanol. After faecal collection, birds were released nearby from where they were trapped. In the laboratory, all faeces were dried in petri dishes. Then the food contents were examined using a stereo microscope and sorted. The plant food items were identified to at least genus by comparing with a seed reference collection which was previously developed from the study site following plant nomenclature from a previous study of vascular plants in this area[17]. Animal remains could be classified only to Order because most were incomplete, rather than intact specimens. The presence of each food component was counted to estimate the percent frequency of occurrence (%F), percent volume (%V), and percent importance value (%IV)[18,19] by following these equations:

Percent frequency of occurrence (%F) = (frequency of each item/ total number of faeces) x 100

Percent volume (%V) = total percent volume of each item/ total number of faeces

Importance value = (%F x %V)/100

Percent importance value (%IV) = (importance value/∑ importance value) x100

The percent volume (%V) of each diet item was determined by visual estimation to the nearest 1% in relation to other items in the same faeces. The food items present in very small amounts were estimated at 1% of volume. We used percent importance values (%IV) for describing the contribution of each food item because it has the benefit of describing food components that occurred frequently but in small amounts in the faecal samples[18].

We collected 35 and 31 faecal samples from *Pycnonotus brunneus* and *P. goiavier*, respectively. Based on the percent importance value (%IV) (Table 1), the diet composition of *P. brunneus* consisted of 97.0% plant items containing at least 13 plants species, and 3.0% comprised of animal parts all of which were insects. For *P. goiavier*, 98.9% of the samples consisted of plant material, of at least 10 species, and 1.1% of the diet components were insects. The three most important items of the *P. brunneus* samples were *Callicarpa arborea* (62.8 %), *Clidemia hirta* (24.7 %) and *Ficus* spp. (5.6 %), whereas in the *P. goiavier* samples, *Ca. arborea* (66.0%), *Melastoma malabathricum* (27.6%) and *Cl. hirta* (3.1%). The native pioneer tree, *Ca. arborea* was the main food resource of both bulbuls as it had the highest percent importance in the diet. Shrubs in family Melastomataceae contributed significantly to the diets of both bulbuls. *M. malabathricum*, a native shrub, was dominant in the diet of *P. goiavier* while

TABLE 1. The percent frequency of occurrence (%F), percent volume (%V) and percent importance value (%IV) of each food item in the faecal analysis of *Pycnonotus brunneus* (N=35) and *Pycnonotus goiavier* (N=31) in an early successional habitat at the Khao Pra Bang Khram Wildlife Sanctuary from November 2011 to October 2012. The plant species with asterisks denote alien species.

Diet types	Order/Family	Species	*Pycnonotus brunneus* %F	%V	%IV	*Pycnonotus goiavier* %F	%V	%IV
Plant Items	Phyllanthaceae	*Antidesma ghaesembilla* Gaertn.	5.71	3.21	0.62	9.68	5.64	1.18
	Phyllanthaceae	*Breynia vitis-ideae* (Burm.f.) C.E.C. Fisc.	-	-	-	3.23	0.81	0.06
	Flagellariaceae	*Flagellaria indica* L.	2.86	0.36	0.03	-	-	-
	Loranthaceae	*Scurrula parasitica* L.	-	-	-	3.23	2.42	0.17
	Melastomataceae	*Clidemia hirta* (L.) D. Don *	28.57	25.67	24.66	16.13	8.87	3.10
	Melastomataceae	*Melastoma malabathricum* L. ssp. *malabathricum*	5.71	1.27	0.24	45.16	28.2	27.55
	Moraceae	*Ficus chartacea* (Wall. ex Kurz) Wall. ex King	11.43	6.74	2.59	3.23	2.42	0.17
	Moraceae	*Ficus* sp.	11.43	7.86	3.02	-	-	-
	Myrsinaceae	*Ardisia quinquegona* Bl.	2.86	0.71	0.07	-	-	-
	Rhamnaceae	*Ziziphus oenoplia* (L.) Mill.	2.86	0.71	0.07	-	-	-
	Rubiaceae	*Ixora cibdela* Craib.	-	-	-	3.23	0.81	0.06
	Rubiaceae	*Lasianthus kurzii* Hk. f. var. *kurzii*	-	-	-	3.23	2.42	0.17
	Cannabaceae	*Trema orientalis* (L.) Bl.	2.86	0.14	0.01	-	-	-
	Lamiaceae	*Callicarpa arborea* Roxb. var. *arborea*	57.14	32.7	62.82	70.97	42.9	65.98
	Lamiaceae	*Vitex* sp.	8.57	8.57	2.47	-	-	-
	Costaceae	*Cheilocostus speciosus* (J.Konig) C.Specht	-	-	-	6.45	3.23	0.45
		Unknown species1	2.86	2.86	0.27	-	-	-
		Unknown species2	2.86	1.43	0.14	-	-	-
Animal items	Hymenoptera		8.57	3.21	0.93	-	-	-
	Coleoptera		2.86	2.14	0.21	-	-	-
		Other Insects	22.86	2.40	1.84	22.58	2.27	1.11

C. hirta, an alien shrub was common in the diet of *P. brunneus*. *C. hirta*, was also marginally present in the diet of *P. goiavier*.

Overall, *Pycnonotus brunneus* and *P. goiavier* were highly frugivorous as fruit contributed to more than 95% of their diets. This high level of frugivory with little insectivory especially outside the breeding period, is also found in other bulbuls including Chinese bulbuls (*Pycnonotus sinensis*)[20], red-vented bulbuls (*Pycnonotus cafer*)[21], red-whiskered bulbuls (*Pycnonotus jocosus*)[4,11]. However, the proportion of arthropods in the diet probably increases during the breeding season because protein is particularly important for developing offspring[22]. For example, it has been suggested that *P. sinensis* increased the animal component of the diet from 1.8% to 55% when breeding[20]. In addition, we observed seasonal fluctuations in the species of fruit consumed by these bulbuls, although our sample sizes were relatively small. *P. goiavier* fed mainly on *Callicarpa arborea* (IV 73%) during the wet season along with a small percentage of *Melastoma malabathricum* (5.4% IV), but the latter fruit (51%) become as important as the former fruit (46%) during the dry season. Similarly, when fruit of *Ca. arborea*, was less available during the dry season, *P. brunneus* feed much more on *Clidemia hirta* and *Ficus*. This seasonal variation appears to reflect the availability of fruit observed in the study area (T. Kerdkaew, pers. obs.).

Our findings indicated that both bulbuls fed primarily on successional plants both native and exotic and may play a key role in seed dispersal of these plants in this area. Invasive plants comprise the majority of the diet of the introduced red-whiskered bulbul (*Pycnonotus jocosus*) on Mauritius, approximately 53%[11] and on Reunion Islands (87%)[4]. Several studies indicate that bulbuls have a high degree of flexibility in their diets as they are found to consume numerous fruiting plants[3, 9]. Generally, bulbuls feed on fruits not larger than 1 cm, the maximum bulbul gape width, and the gape width of red-whiskered bulbul, *P. jocosus*, which has similar body size of our study species, is 9.7 mm[23]. When feeding on fruits, bulbuls typically swallowed them whole and carried seeds in their gut, which could also have additional positive effects on germination[3]. For example, it has been found that ingested seeds of *Clidemia hirta*, which passed through the bulbul gut, germinated faster than seeds that had not passed through the gut and also had higher germination success[15]. Quantitatively, red-whiskered bulbuls (*P. jocosus*) in Reunion Island could defecate up to 2,000 *Cl. hirta* seeds per dropping[4]. This evidence suggests that bulbuls can be effective seed dispersers of both native and exotic plants. We also observed other bulbuls, such as olive-winged bulbul (*P. plumosus*), and flowerpeckers, such as scarlet-backed flowerpecker (*Dicaeum cruentatum*) and orange-bellied flowerpecker (*D. trigonostigma*), feed on *Cl. hirta* (T. Kerdkaew, unpubl. data).

Currently, *Clidemia hirta* has been reported as an invasive species in South-East Asia. This exotic species can be found in dense colonies in secondary forests, forest edges, forest gaps, trails and also in open areas which are relatively moist and shady[24]. It has also invaded the understories of vast areas of secondary and primary forest in Singapore[25] and at Pasoh in Malaysia by competing with native plants that depend on gaps as their primary habitat for establishment[12]. In some areas of Thailand, this shrub has gradually expanded its distribution and has become a major weed in rubber and oil palm plantations (J. Sae Wai, pers. obs.). Invasive plants such as this can directly and indirectly affect native fauna. For example, the invasive plant, *Lantana camara* L., decreased the diversity of canopy and insectivorous birds in deciduous forest in southern India[26]. It is therefore extremely important to monitor the invasion of *Cl. hirta* into tropical forest of South-East Asia, a global biodiversity hotspot[27]. To date however, there is very limited literature available on the effects of invasive plants on native organisms in this region.

In South-East Asia, large areas of forest have been converted for agriculture especially rubber (*Hevea brasiliensis* Müell. Arg.) and oil palm (*Elaeis guineensis* Jacq.)[28] and thus causing habitat fragmentation[29,30]. Landscape fragmentation can cause significant increases in exotic plant dispersal, as some native frugivores predominantly forage in edge habitats where many invasive plants colonize[31]. Since exotic plants have the ability to alter landscape communities and often tolerate disturbance more than native plants[32], such interactions may accelerate the invasion process of *Clidemia hirta* in the lowland tropical forests of this region. Currently, it is still unknown whether the introduced *Cl. hirta* can alter native community interactions, and therefore further intensive studies as well as management are likely needed to control such alien plant invasions in lowland tropical habitats.

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Home range and habitat use of two indigenous birds, red-eyed bulbul (*Pycnonotus brunneus*) and yellow-vented bulbul (*Pycnonotus goiavier*) in a tropical lowland forest, Krabi, southern Thailand.

Abstract

Home range and habitat use studies can provide understanding of behaviours and area requirements of such animal which may benefit biodiversity conservation. We examined home range size and habitat used by Red-eyed bulbul (*Pycnonotus brunneus*) and yellow-vented bulbul (*P. goiavier*) relatively common birds tropical lowland area by radiotelemetry. The mean 95% Minimum Convex Polygon home range of red-eyed bulbul (7.09 ± 4.89 ha.) was significantly larger than of yellow-vented bulbul (2.68 ± 1.60 ha.). Also the mean core area size (50% MCP) of red-eyed bulbul (1.39 ± 1.06 ha.) was significantly larger than of yellow-vented bulbul (0.46 ± 0.15 ha.). Both bulbuls showed the non random habitat used. Based on the compositional analysis, red-eyed bulbul mostly selected transition zone equal to forest interior, followed by open grassland, oil palm and rubber plantation, respectively. Yellow-vented bulbul almost used only open grassland. Red-eyed bulbul presented nomadic behaviour at some point as they move to many habitat types and lead to increasing of home range. However, yellow-vented bulbul was sedentary which frequently used open grassland, and it rarely moved to other habitats. The difference in home range sizes and habitat uses of these bulbuls may be caused by the resource partitioning, following of preferred food resources, territorial behaviour, breeding season, or group size.

Key Words: *Pycnonotus brunneus*, *P. goiavier*, radiotelemetry, home range, habitat use, tropical lowland habitat.

Introduction

Bulbuls play important role in seed dispersal in tropical forest (Corlett, 1998). Red-eyed and yellow-vented bulbuls, the resident birds, are amongst the most common bird found in early successional vegetation in southern Thailand (Round and

Brockelman, 1998 ; Sritongchuay *et al*, submitted) These bulbuls are habitat generalist, with some suggestion that yellow-vented bulbul prefers open area (Kobkhet, 2001 ; del Hoyo *et al*, 2005 ; Nabhitabata *et al*, 2008 ; Wee, 2009). Currently, there are a few studies on the home range size and habitat use of bulbuls (eg. Lambert, 1989; Chaikuad, 2000; Peh and Ong, 2002; Tanasarnpaiboon, 2008), and their habitat uses are still not well understood.

Home range study relates directly to resource utilization and area requirement for species which directly benefit in conservation area and habitat requirement for them (Peh and Ong, 2002). Specifically, home range is the area that animal used for living activities such as foraging for a food, mating and nestling caring (Burt, 1943). Moreover, home range study reflects the movement characteristics of such animal and relate directly with their ecosystem services, for example seed dispersal (Fukui, 1995). Habitat use is the usage of both abiotic and biotic resources in such area, and it can reflect of animal behaviours, for example, foraging, territory, reproduction (Krausman, 1999). For those life history characteristics, some of these behaviours may need specific habitat. The foraging habitat possibly consisted of the same habitat requirements for protection or shelter (Litvaitis *et al.*, 1996). Each animal may have its own habitat characteristics, and can be varied among season (Krausman, 1999). The habitat use of animal suggests the site that seeds carried by dispersers potentially deposited. So the habitat use of seed dispersers will consequently result in micro site selection of dispersed seeds, which may affect seed dispersal effectiveness (Schupp, 1993). In this study, we applied radiotracking to investigate the home range size and habitat selection of red-eyed and yellow-vented bulbuls in a tropical lowland forest in southern Thailand.

Methods

Study site

The present study was conducted in the Khao Pra Bang Khram Wildlife Sanctuary located in Krabi province, Southern Thailand (8°10’ N and 98°80’ E). The sanctuary was founded in 1993. The majority of area is lowland tropical forest which elevation ranges from 25-75 m. a.s.l. Primary evergreen to seasonal forest, and mixed floras of hardwoods and bamboos are mainly found in this sanctuary (Maxwell, 2009). There is a swamp forest and hot spring located in the sanctuary. Moreover, open grassland and early successional area are presented. Vegetative structure is entirely covered by a grass, *Imperata cylindrica* and a small shrub, *Melastoma malabathricum*. *Callicarpa arborea*, *Antidesma ghaesembilla,Vitex pinata* and *Ficus hispida* are the major woody trees in this area. There is a running stream from the center to the east of this open area. Previously, it was disturbed by human for the agricultural purposes. The area size is around 20 hectares. It mostly surrounded by primary lowland evergreen forest. The major tree is *Dipterocarpus kerrii*. The understory zones are numerous with treelets, shrubs, lianas, and seedlings of various plants. The common treelets and shrubs are *Clausnea excavata*, *Leea indica*, *Psychotria curviflora*, *Breynia vitisideae* and *Pandanus ovatus.* Lianas are commonly found also, for example, *Tectaria loureiri*, *Uvaria cordata* and *Entada rheedei* (Maxwell, 2009). Bamboos (Bambusoideae) are numerous, and some of Palmae, such as *Orania sylvicola* and *Salacca* spp, are found. In buffer zone, approximately 50 m wide between forest and open area, the plant structure is mostly shrub species and woody climbers, for example, *Ficus chartacea*, *Melastoma malabathricum, Ziziphus oenoplia.* The introduced fruiting shrub, *Clidemia hirta*, is commonly found in this area. There is only 16% of forest in this sanctuary (Maxwell, 2009). The protected area is mostly surrounded by the vast area of rubber plantations, oil palm plantations and human-dominated landscapes. The majority of oil palm and rubber plantations around the protected area are older than 15 years. Most of them are dominated by understorey plants, for instance, *Selaginella willdenowii*, *Melastoma malabathricum*, *Musa acuminata*. The exotic Melastomataceae, *Clidemia hirta* is a major weed in these areas.

In the study area, the climate is classified as tropical wet seasonal (Walsh, 1996). with an annual accumulative rainfall was 2,905 mm in the study period (November 2011 to October 2012). However, during the study period, there was not clearly identified wet and dry season. In this case, we assumed that there was all year wet season as the monthly rainfall is mostly higher than 60 mm. indicating for the tropical rainforest climate by the Köppen-Geiger system (Peel *et al*, 2007). Except in February, the accumulative rainfall was 89.4 mm. Rainfall was peaked in January

2012, approximately 490 mm, influenced by the tropical storm. The monthly rainfalls are high in May to September which mainly higher than 300 mm. per month.

Radiotelemetry

Birds were captured by mist nests in the field site from November 2011 to December 2012. Every month, six mist nests were set in the early morning (0700h) to evening (1700h) for 2 days, and they were monitored every ten minutes. When birds were caught, they were weighted, measured and breeding status were identified. Birds were equipped with radio transmitters (BD-2, Holohil Systems, Canada) following the leg loop harness suggested by Rappole and Tipton (1991). By applying this attaching method, the transmitters are likely to drop out after a few weeks when the harness ring is torn. The transmitter weight is1.2 g. which is around 4.5% of mean bird weight. We assumed that there were not any drawbacks to bird behavior as the transmitter weight is lower than 5% of the bird weight (Cochran, 1980). All birds were tagged with light-weight aluminum leg band in order to avoid resampling and to relocate when the transmitter was fallen off. Tagged birds were monitored and recorded fixes for three hours/day for at least five to eight days, separated to morning (0700h – 1000h) and afternoon (1400h – 1700h) sessions. We assumed that the tracking duration of each bird is enough to record fixes to draw home range which the majority of bird's home ranges accumulation reached the asymptote (Fig. 1). Locations of tagged bird were recorded with GPS (Garmin GPS Map 60CSx, ± 5 m. accuracy) by homing in method using receivers, TRX-48S (Wildlife Materials Inc., USA) and hand-held 3 elements Yagi antennas. We always kept the distance from the bird at least 20 m to avoid the interference by observer to bird. Before attaching to the birds, all transmitters were tested for the signal strength at different distances in order to estimate the distance between observer and bird if tagged birds can not clearly located. Range finder was used to measure the distance between observer and bird when bird was clearly seen by eyes. By the real time tracking, we assumed that the error of fixes location is lower than 10 m. as all birds were followed and recorded for the locations continuously. The habitat were categorized into 5 types: inner forest, edge or buffer zone which is the area located in radius 50 meters between inner forest and open grassland, open area or grassland, rubber plantation and oil palm plantation. Each fix were noted, and the time budget was calculated by the summation of time budget between fixes in each habitat type of overall tracking data.

Data analysis

Home range sizes of birds were calculated individually with 95% minimum convex polygon (MCP), and core area sizes of all individuals were estimated with 50% MCP using Home Range Tools with fixed mean selected in ArcGIS 9.3 (Rodgers and Kie, 2011). This method has several benefits. For example, the result from this home range calculation can be comparable with other studies in bulbuls which most of them applied this method (Fukui, 1995; Peh and Ong, 2002; Weir, 2004; Tanasarnpaiboon, 2008). Moreover, the MCP method allows us to detect the long distance movement of birds as the outermost fixes were used to draw home ranges (Weir, 2004). In this study, overlap area of each individual of both species were not calculated because we did not monitored a large number of birds at the same period (1-2 birds per month per species). The difference of home range and core area sizes between 2 birds species were analysed by independent sample t-test, and log transformation was applied when data were not normally distributed, or non parametric statistics, Mann-Whitney U test was performed instead of parametric statistics.

The habitat used of *Pycnonotus brunneus* and *P. goiavier* were performed by compositional analysis (Aebischer *et al.*, 1993). This method allows us to compare the proportion of habitat availability, in this case, size of each habitat type, within home range with the proportion of habitat utilization which is the proportion of time use in each habitat. Time uses in each habitat (U_i) were weighted relatively to another habitat (U_j), following the log ratios calculation, $\ln(U_i/U_j)$. The log ratios of habitat availability were calculated following $\ln(V_i/V_j)$ similarly to the log ratios of time use. In this study, we chose oil palm plantation (PALM) as the weight habitat because it was utilized least by both 2 bulbuls, based on the lowest time budget. The difference of $\ln(U_i/U_j) - \ln(V_i/V_j)$ was calculated to investigate the preferences of habitat i and j. It is possible that some habitats were presented but not utilized by birds and cause 0 values, so the 0.01 values were substituted for those 0 values. These replacement values were certainly lower than the least habitat use proportions as suggested by Aebischer et al. (1993). Multivariate analysis of variance (Wilk's lambda) was used to test for the randomization of habitat preferences. One sample t-test was used to test for the mean difference of each habitat selection which was comparable to PALM. For the compositional analysis of *P. goiavier*, the forest habitat was omitted because no bird used this habitat during observations. The mean of other habitat selections were compared using paired t-test. All time uses of birds in each habitat were pooled in order to describe to habitat time budget of each bird species. Other factors, such as, seasonal variation and breeding status might affect the habitat selection of birds. In this study, we did not separate analysis following these factors because all birds captured were not the breeding birds as they did not express any breeding behaviour, such as caring young or nest guarding. Moreover, there was not clear to identify dry season in the study site as the accumulative rain fall is higher than 100 mm for almost month except in February, approximately 89 mm, indicating for whole year wet season.

Arithmetic mean and SD were reported for all information, and statistical analyses were performed in SPSS 15.0 .

Results

Home range size and habitat use

The home range size (95% MCP) of 13 *P. brunneus* ranged from 2.20 to 19.07 ha, and mean home range size was 7.09 ± 4.89 ha, median = 4.79 ha. Some birds (bird number 889, 410 and 417) tended to have bigger home range sizes than others (Table 1 and Figure 1a). For *P. goiavier*, 95% MCP home range sizes of 10 birds were between 1.42 to 6.69 ha, and mean home range size was 2.68 ± 1.60 ha, median = 2.01 ha (Table 3 and Figure 1b). There were significantly different between log 95% MCP home range sizes of two bulbuls (t-test: $t = 3.650$, $df = 21$, $P = 0.001$). Clearly, the mean home range size of *P. brunnues* was bigger than of *P. goiavier*.

The core area size (50% MCP) of 13 *P. brunneus* ranged from 0.48 to 3.85 ha, and mean core area size was 1.39 ± 1.06 ha, median = 0.94 ha (Table 1 and Figure 3a). However, the mean core area size of *P. goiavier* was 0.46 ± 0.15 ha, median = 0.42 ha and ranging from 0.25 to 0.71 ha (Table 3 and Figure 3b). There were significantly different between core area sizes (50% MCP) of two bulbuls (Mann-Whitney U-test: U = 13, P = 0.001). Mostly, the pattern of fixes was likely clumped in each observation day which suggests that both bulbuls rarely had long distance movements for daily ranging behaviour.

The overall habitat selection of *P. brunneus* was not random ($\lambda = 0.012$, $P < 0.001$), indicating that birds preferred one habitat more than others. According to the compositional analysis, the interpretation of habitat selection was EDGE = FOREST > GRASS >>> PALM > RUBBER. It is noticeable that *P. brunneus* used edge forest or buffer zone equally to inner forest. These two habitats were more utilized than grassland and noticeably higher used than agricultural patches, oil palm plantation and rubber plantation (Table 2). The habitat use of *P. goiavier* was not random ($\lambda = 0.02$, $P < 0.001$). The habitat preference of *P. goiavier* was noticeably different from *P. brunneus*. *P. goiavier* selected grassland as the main habitat, and the overall habitat use of this bird was GRASS >>> PALM = EDGE > RUBBER (Table 4).

Discussion

Our study indicated that the home range and core area sizes of red-eyed bulbul (*Pycnonotus brunneus*) were bigger than of yellow-vented bulbul (*Pycnonotus goiavier*). Some individuals of red-eyed bulbul were likely nomadic as their range sizes increased gradually in a short period tracking time (more than 10 ha), and lead to the increase of home range size. Our finding can be comparable with the range size of black-and-white bulbul (*Pycnonotus melanoleucos*) which its range size was approximately 50 ha in seven days tracking period in a Malaysian lowland rain forest, so it was suggested that this species was nomadic (Lambert, 1989). Also, in Hong Kong shrubland, light-vented bulbul (*Pycnonotus chinensis*) and red-whiskered bulbul (*Pycnonotus jocosus*) were nomadic at some point (Weir, 2004). Moreover, Mokotjomela et al, (2013) reported that cape bulbul (*Pycnonotus capensis*) could extend range up to 200 km based on mark and recapture method in South African Mediterranean. The first reason to explain the larger home range size of red-eyed bulbuls may be they followed pattern of their favored fruit production (Lambert, 1989). Other explanation may be the fruit abundant during tracking time was low so that birds tended to move farer to obtain enough food resources (Weir, 2004) and lead to the increase of home range size. Another reason may be the habitat generalist of red-eyed bulbul which they used more varied habitat than yellow-vented bulbul. In this study, forest interior and transition zone were the most common used habitat by red-eyed bulbul, which similar to other reports (Khobket, 2001; del Hoyo *et al*, 2005). The habitat characteristics, such as vegetative composition, may influence the foraging behaviour in birds (Smith, 1990). In forest interior, the flora structure was mostly tall tree, high density of canopy (Maxwell, 2009).

In this study, the red-eyed bulbul number 416 that was tracked in August 2012 spent all time use in forest interior. In transition zone, most of plants were dense shrub, small trees and most of them were an early successional species, for example, *Ficus chartacea* and Melastomataceae shrubs. These plants were highly abundant in this area, produced fruit all year round (Maxwell, 2009) and included in red-eyed bulbul diet (Kerdkaew *et al*, 2014). Because of this feature, some red-eyed bulbuls primarily spent their time in transition zone. In open grassland, red-eyed bulbuls sometimes used this area, mainly feeding on open area plants, for example, *Callicarpa arborea* and *Melastoma malabathricum*. These two plants produced fruit throughout the year, and they may be the alternative food resources for red-eyed bulbul. Also, this area was adjacent to transition zone and forest area so that this area was easy to access by red-eyed bulbul. Moreover, the habitat selection pattern of red-eyed bulbul was similar with puff-throated bulbul (*Alophoixus pallidus*) and grey-eyed bulbul (*Iole propinqua*) which used evergreen forest equally to transition zone in Khao Yai National Park, northeastern Thailand (Chaikuad, 2000). Fruit productivity in forest showed highly seasonal fluctuation (Mulwa *et al*, 2013). It has been suggested that most forest plants in this area produced fruits during the peak of raining season in July-September (Maxwell, 2009). During this time, some red-eyed bulbul may use forest more than other habitats as fruits were high availability. Also, we found that some red-eyed bulbuls which mostly strict in transition area or forest interior foraged at fruiting trees, such as, *Callicarpa arborea* and *Antidesma ghaesembila* in open grassland habitat. This caused the increase of home range size as these birds moved out from edge or forest area to grassland where far away from their normal range, approximately 0.5-1 km. Moreover, another study on common bulbul, *Pycnonotus barbatus*, showing that this species was abundant in forest and farmland habitat which mostly open, and it was the commonest species visiting the transition area between forest and farmland. Thus, it was able to use vary habitat types in order to track fruit production (Menke *et al*, 2012 ; Mulwa *et al*, 2013). However, red-eyed bulbul rarely used oil palm and rubber plantation indicating that the agricultural habitat was avoided. These areas were disturbed by human activities, such as, crop harvesting and land management so that these area may not appropriate to use by this bird. However, the red-eyed bulbul number 886 mostly spent its time in rubber plantation which adjacent to forest. This rubber plantation was an old growth, around 20 year old, and fully covered with the fruiting shrub, *Clidemia hirta*, on the understorey zone. del Hoyo et al. (2005) suggested that it is possible to find red-eyed bulbul in the mature rubber plantation locating near forest, but rarely. In this case, by the high abundant of *C. hirta* in this rubber plantation, it is possible that *C. hirta* provided enough food for the no. 886 red-eyed bulbul to live in agricultural zone.

However, yellow-vented bulbul was more sedentary in comparison with red-eyed bulbul, and mean home ranges size was small (mean 2.68 ha) which mean that birds used the same area continuously. Moreover, one yellow-vented bulbul (no. 887) was recaptured at the same netting site in September 2012, seven months after tracking, suggesting that this bird may not move to other areas. Likewise, many species of bulbuls were reported as the sedentary birds, for example, olive-wing bulbul, *Pycnonotus plumosus* (mean home range, 2.17 ha) and cream-vented bulbul, *Pycnonotus simplex* (mean home range, 3.53 ha) in a lowland secondary forest, Singapore (Peh and Ong, 2002), and puff-backed bulbul (*Pycnonotus eutilotus*) in a malaysian lowland evergreen dipterocarp forest (Lambert, 1989). The mean home range size of yellow-vented bulbul was similar to the puff-throated bulbul which was 2.4 ha in one year round, Khao Yai National Park, northeastern Thailand (Tanasarnpaiboon, 2008). The reason for this finding may be the habitat preference. The yellow-vented bulbul never used forest interior, rarely spent its time along forest edge. More than 90% of time spent was on open grassland area. Likewise, this bird is an open area species, and it can be found in much kind of habitat which very open; mangrove and swamp forest, secondary growth, grassland, park, garden, cultivation (Khobket, 2001 ; del Hoyo, 2005). Yellow-vented bulbul foraged mostly in open grassland and almost diet of it was open area plants. *Callicarpa arborea* and *Melastoma malabathricum* were main food resources of this bird, 71.11% of overall diet (Kerdkaew *et al*, 2014), and these plants were super abundant resources as they covered almost open grassland area, especially the *M. malabathricum*, and fruiting throughout the year (Leeratiwong *et al*, 2009; Maxwell, 2009). Thus it is not necessary to search for food resources in other area as this open area may provide enough food for yellow-vented bulbul. There was one yellow-vented bulbul (no. 413) that moved out to the rubber plantation, but we assumed that it was an exploratory behaviour as this bird used the rubber plantation for a temporary period and then moved back to open grassland. Chaikuad (2000) suggested that grassland was the optimal habitat for red-whiskered bulbul, *Pycnonotus jocosus*, because it provided nest sites and food resources. This could be described in the habitat selection of yellow-vented bulbul also as we found this bird foraging and breeding totally in grassland area.

Territorial behaviour may be the factor affecting home range sizes of animal. In our study, we found that *P. goiavier* showed some territorial behaviours, for example intraspecific aggression, revisit same fruiting tree in a short period. Also, the mean core area of its is smaller than of *P. brunneus*. Similarly, in puff-throated bulbuls (*A. pallidus*), a territorial bird, its home range size, median, 1.37 ha, ranging from 0.29-5.58 ha, was small (Thanasarnpaiboon, 2008), and it presented similar territorial behaviour to *P. goiavier* e.g. feeding on the same tree in short time (Khamcha *et al*, 2012). Moreover, red-whiskered bulbul (*P. jocosus*) was reported as territorial species in wild habitat with 0.6 ha in territory size (Chaikuad, 2000) and in semi-wild habitat, 0.3 ha in territory size (Sotthibandhu, 2003), and it can be comparable with *P. goiavier* as it showed aggressive behaviour also. However, it needs more intensive observation to support this argument.

It is possible that breeding status might affect home range sizes of bird. Male Great Hornbill (*Buceros bicornis*) and Wreathed Hornbill (*Rhyticeros undulatus*) showed the smaller home range size in breeding season because it is possible that male Hornbills had to provided enough food for their fledglings in nest cavity and nest guarding (Poonswad and Tsuji, 1994). In male chaffinches, there was smaller home range when defending nest (Hanski *et al*, 1992). Also in lesser spotted woodpecker (*Dendrocopos minor*), home range was the smallest in breeding season in comparison with other seasons (Wiktander *et al*, 2001). In contrast, breeding cream-vented and olive-winged bulbul females increased their home range sizes in order to obtain more food for their young (Peh and Ong, 2002). However, we could not capture any breeding birds in this study, so there was no data to prove the effect of breeding season on home range size of yellow-vented and red-eyed bulbuls.

Group size may be one factor that relates to the changing of home range size. Tanasarnpaiboon (2008) found out that the co-operative breeding puff-throated bulbul (*Alophoixus pallidus*) increased home range size in post-breeding season, and the home range size of group with juvenile was larger than the group without juvenile in this season. It has been suggested that when the group becomes larger, the home range size tended to increase in order to serve optimal area for food searching (Tanasarnpaiboon, 2008). In the study site, we also noted that red-eyed bulbul could form a single species group consisting of more than 10 individuals (Kerdkaew, per. obs.), and also forming mixed species flock with other bird species, for example, other bulbuls and leafbirds. (del Hoyo *et al*, 2005). With group forming characteristics, it is possible that the home range size and characteristics of red-eyed bulbul may be different in relation to group size. However, there was insufficient intensive data to support this point.

However, in this study, all birds were tracked in short time period (4-8 days). Therefore, it is possible that the home range sizes may underestimate, and habitat use may not be generalisation. If we increase the tracking time, the home range sizes of birds may be larger, especially for red-eyed bulbul as most home range did not reach the optimal size. For yellow-vented bulbul, the home range size was likely generalization because the ranging pattern was similar for all tracked birds. Furthermore, the home range sizes of bird may change if we track more individuals of both species. However, due to the limit of transmitter number, we could not track more birds during field study.

Since this study provided data on the home range size and habitat use of two common frugivorous species, this work is an initiation to investigate the role of these birds on seed dispersal service in lowland tropical habitat. Based on their different home range size and habitat used, these may relate to the different seed dispersal quality in term of seed dispersal distance and seed site deposition provided by red-eyed and yellow-vented bulbul.

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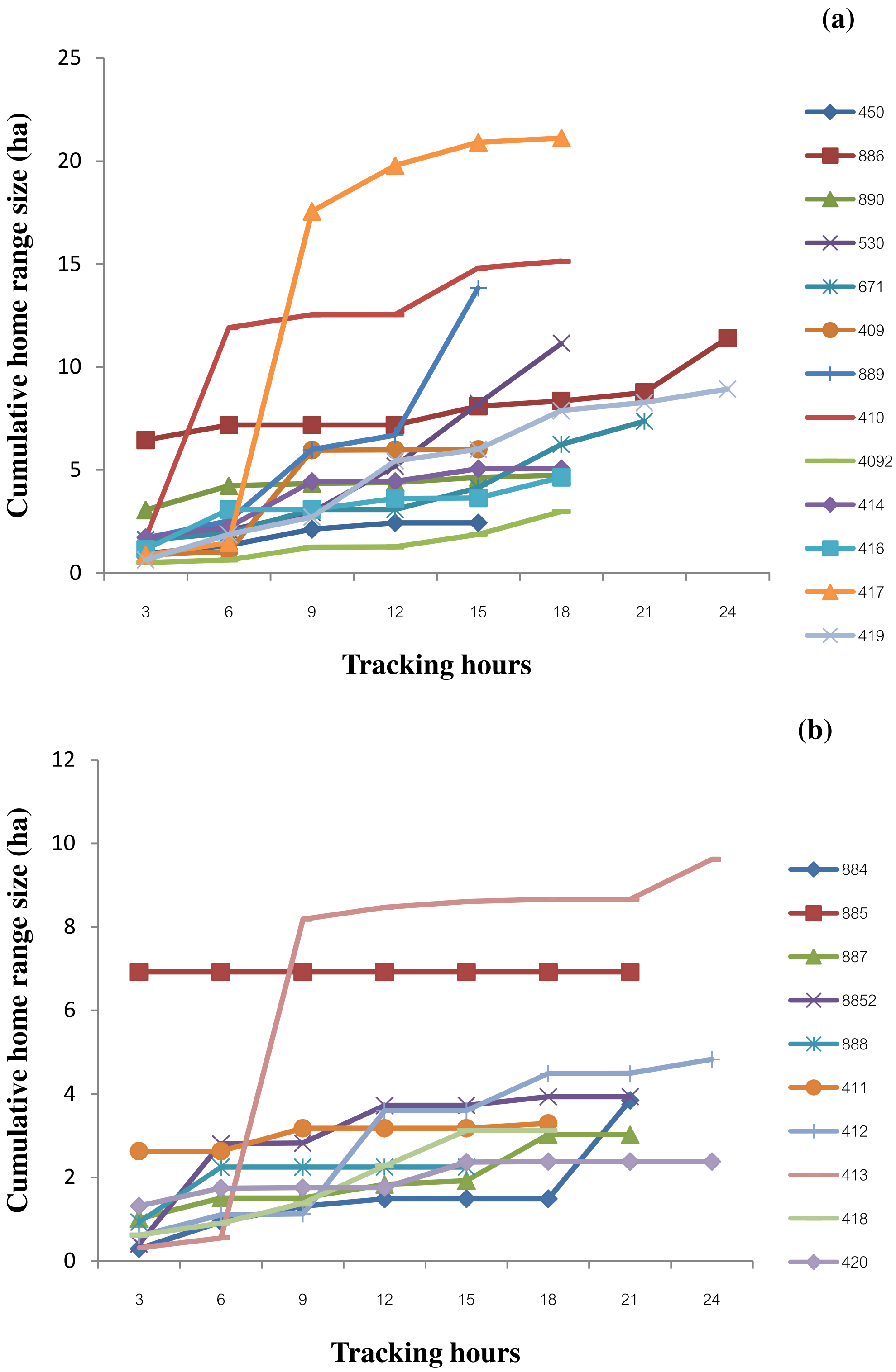


Figure 1. Cumulative 100% MCP home range size of 13 red-eyed bulbuls, *P. brunneus* (a) and 10 yellow-vented bulbuls, *P. goiavier* (b) in Khao Phra Bang Khram Wildlife Sanctuary, Tropical lowland habitat, Krabi, southern Thailand

Table 1. 95% MCP home range sizes and relevant information of 13 red-eyed bulbuls (*Pycnonotusbrunneus*) KhaoPhra Bang Khram Wildlife Sanctuary, Tropical lowland habitat,Krabi, southern Thailand.

Bird number	Total hours track	Fixes number	95% MCP home range (ha)	50% MCP core area (ha)	Tracking period
450	12.5	58	2.20	0.49	8-21 DEC 2011
886	21.5	184	8.45	1.41	24 FEB - 16 MAR 2012
890	18	129	3.26	0.85	21-27 MAR 2012
671	21	133	4.78	0.48	12-20 APR 2012
530	18	103	7.07	0.94	21-23 APR 2012
889	15	83	11.40	2.02	13-18 MAY 2012
409	15	90	4.79	0.65	21-25 MAY 2012
4092	18	78	2.62	0.49	12-18 JUN 2012
410	18	90	13.00	3.85	12-19 JUN 2012
414	18	90	4.42	0.85	13-18 AUG 2012
416	18	97	3.66	0.97	20-26 AUG 2012
417	18	95	19.07	2.01	15-23 SEP 2012
419	24	113	7.40	3.04	16-24 OCT 2012
Mean (SD)	18.08 (2.96)	103.31 (31.48)	7.09 (4.89)	1.39 (1.06)	
Median	18	95	4.79	0.94	

Table 2. Compositional analysis of habitat used by 13 red-eyed bulbuls including the availability in their home ranges in KhaoPhra Bang Khram Wildlife Sanctuary, Tropical lowland habitat,Krabi, southern Thailand. Habitat types: PALM – oil palm plantation, RUBBER – rubber plantation, FOREST - inner forest, EDGE - edge forest, GRASS – grassland. The differences of mean log-ratios among habitat types were analysed following one-sample and paired t-test (df = 12). (* indicated for $P < 0.05$, ** indicated for $P < 0.001$)

Habitat types	PALM	RUBBER	FOREST	EDGE
GRASS	3.371 *	4.674 *	-3.101 *	-2.888 *
EDGE	6.259 **	7.562 **	-0.213	
FOREST	6.472 **	7.775 **		
RUBBER	-1.304 **			

Table 3. 95% MCP home range sizes and relevant information of 10yellow-vented bulbuls (*Pycnonotusgoiavier*) in KhaoPhra Bang Khram Wildlife Sanctuary, Tropical lowland habitat,Krabi, southern Thailand.

Bird number	Total hours track	Fixes number	95% MCP home range (ha)	50% MCP core area (ha)	Tracking period
884	21	88	1.78	0.60	7-18 JAN 2012
887	21	154	1.82	0.43	25 JAN - 20 FEB 2012
885	21	139	3.63	0.39	26 JAN - 19 FEB 2012
8852	21	136	1.90	0.29	12 - 20 APR 2012
888	15	98	1.42	0.25	13-17 MAY 2012
411	18	105	2.12	0.41	21- 26 JUN 2012
412	24	137	3.38	0.71	18-26 JUL 2012
413	24	135	6.69	0.50	18-26 JUL 2012
418	18	76	2.55	0.60	15-23 SEP 2012
420	24	110	1.53	0.37	16-24 OCT 2012
Mean (SD)	20.70 (2.98)	117.80 (25.84)	2.68 (1.60)	0.46 (0.15)	
Median	21	122.5	2.01	0.42	

Table 4. Compositional analysis of habitat used by 10 yellow-vented bulbuls including the availability in their home ranges in KhaoPhra Bang Khram Wildlife Sanctuary, Tropical lowland habitat,Krabi, southern Thailand. Habitat types: PALM – oil palm plantation, RUBBER – rubber plantation, EDGE - edge forest, GRASS – grassland. The differences of mean log-ratios among habitat types were analysed following one-sample and paired t-test (df = 9). (* indicated for $P < 0.05$, ** indicated for $P < 0.001$)

Habitat types	PALM	RUBBER	EDGE
GRASS	4.033 **	5.168 **	4.747 *
EDGE	-0.714	0.421	
RUBBER	-1.135 *		

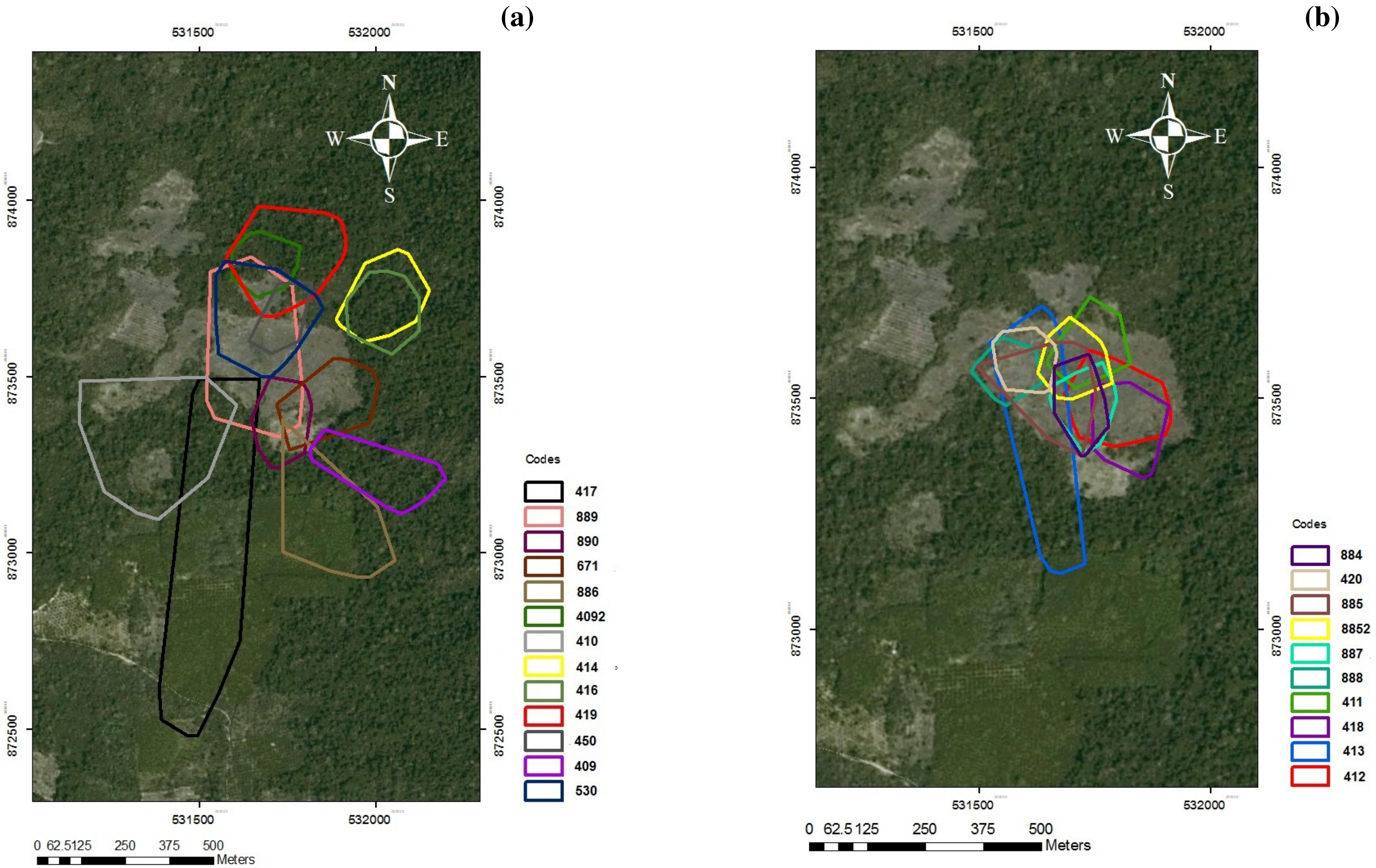
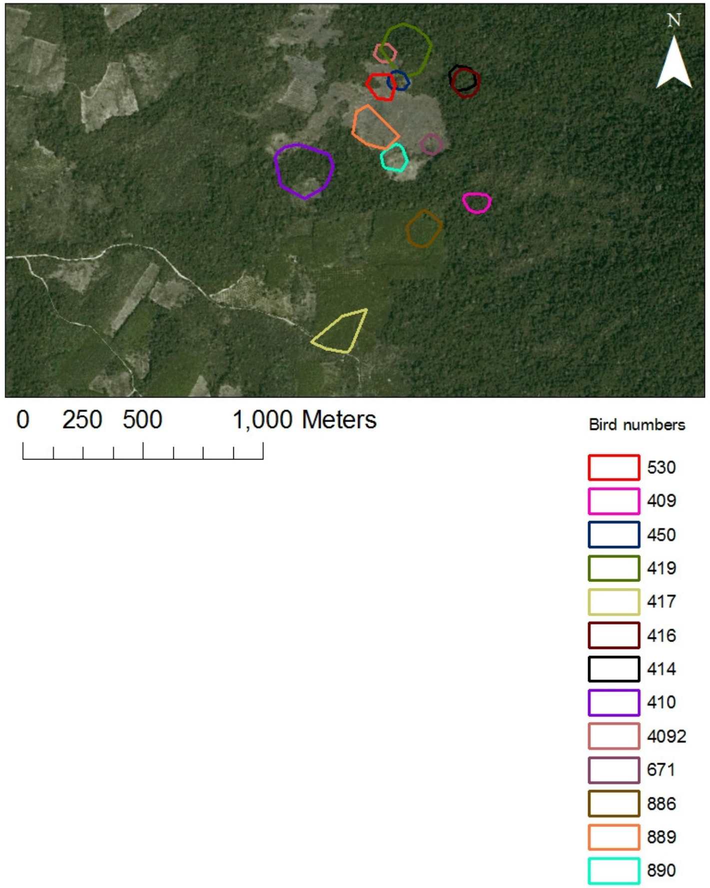


Figure 2. 95% Minimum Convex Polygon (MCP) home range sizes of 13 red-eyed bulbuls, *P. brunneus* (a) and 10 yellow-vented bulbuls, *P. goiavier* (b) in Khao Phra Bang Khram Wildlife Sanctuary, Tropical lowland habitat, Krabi, southern Thailand.

(a)



(b)

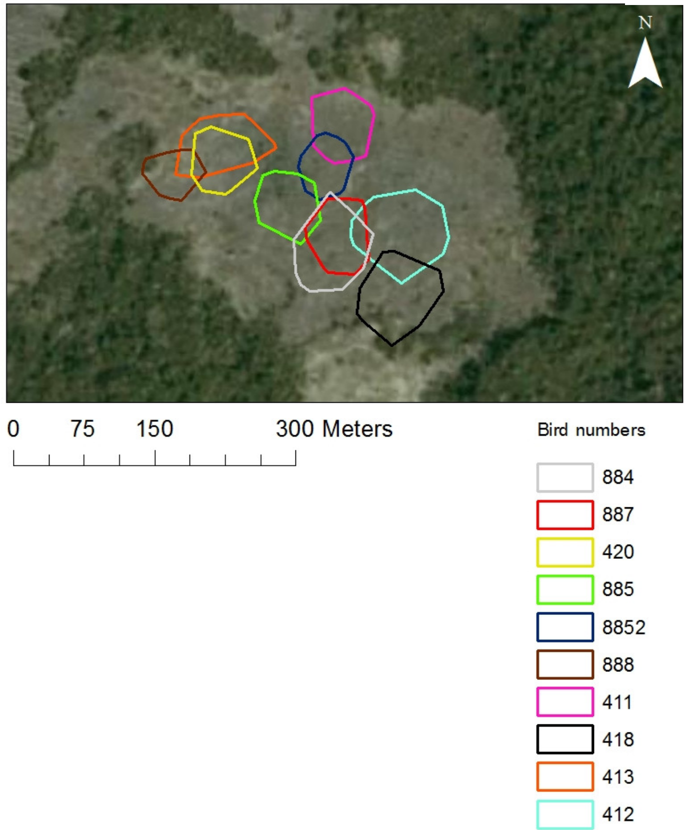


Figure 3. 50% Minimum Convex Polygon (MCP) core area sizes of 13 red-eyed bulbuls, *P. brunneus* (a) and 10 yellow-vented bulbuls, *P. goiavier* (b) in Khao Phra Bang Khram Wildlife Sanctuary, Tropical lowland habitat, Krabi, southern Thailand

Effective seed dispersal of an early successional tree (*Callicarpa arborea* Roxb.) provided by two common bulbuls in lowland tropical habitat, southern Thailand

Abstract

Each animal disperser can provide different seed dispersal patterns. We examined the quantitative seed dispersal, seed shadow and seed deposition site of *Callicarpa arborea* (Lamiaceae) by two common bird species, red-eyed bulbul (*Pycnonotus brunneus*) and yellow-vented bulbul (*P. goiavier*), in an early successional habitat in southern Thailand. Mean fruit removal/hr. of *P. goiavier* (4.4 ± 4.83 fruits/hour) was significantly higher than of *P. brunneus* (1.9 ± 2.53 fruits/hour), indicating higher seed dispersal quantity. Mean feeding time and number of fruit removed/visit, were not significantly different. Fruits tended to be removed mainly in the morning and late afternoon by these 2 bulbuls. There was positive correlation between ripe fruit phase score and mean fruit removal/hr, but no correlation between mean time spent on *C. arborea* tree and the ripe fruit phase score. Mean seed passage time of these two bulbuls was not significantly different. All seeds passed within 60 min, after feeding on fruits. More than 90% of seeds were dispersed away from the parent tree by these bulbuls. However, the site deposition of seed was different. In *P. brunneus*, most seeds were dropped in transition zone 50 meters buffer zone between inner forest and open grassland (55.0%), but seeds were always deposited in grassland by *P. goiavier* (97.5%). As *C. arborea* is a pioneer plant which only found established in non-forest areas, *P. goiavier* was likely to carry seeds to suitable site. It can be concluded that *P. goiavier* is higher effective seed disperser of *C. arborea* than *P. brunneus*.

Key Words: *Pycnonotus brunneus*, *P. goiavier*, *Callicarpa arborea,* frugivore assemblage, seed shadow, seed deposition site, lowland tropical habitat.

Introduction

More than 10^9 hectares of global forest habitats will be converted to agricultural area by 2050 (Tilman *et al*, 2001). Focusing on Southeast Asia, the deforestation has highest relative rate in comparison with other tropical habitats, and this may lead to the disappearance of 75% of forest area by 2100 and up to 42% biodiversity loss (Sodhi *et al.*, 2004). However, there opportunities to restore some this habitat as reverts from agriculture back to some form of natural vegetation (see Elliott *et al*, 2003, Tunjai, 2011). Early successional habitat is mostly covered by grasses, treelets and small shrubs, provided feeding and nesting site for some open area animals, such as small birds and mammals (Smith, 2007) However, this area still needs biotic seed dispersers to increase the soil seed bank which is mostly insufficient (Duncan and Chapman, 1999). Seed disperser has benefit on plants by moving seeds away from parent trees, promoting seedling survival and increasing the chance in colonising on the new suitable area (Howe and Smallwood, 1982). Moreover, each animal disperser can provide different quantitative seed dispersal in term of visitation rate and fruit removal rate (Graham *et al*, 1995; Jordano and Schupp, 2000; Mishra *et al*, 2007), and other aspect of animal seed disperser also, such as seed shadow, the spatial distribution of seeds distributed from a parent plant, (Westcott *et al*, 2005; McConkey and Chivers, 2007; Khamcha *et al*, in press) and seed deposition site (McConkey and Chivers, 2007).

Bulbuls (Family Pycnonotidae), are mentioned as playing a role in seed dispersal in the Oriental region (Corlett, 1998a). They interact with several plants species by feeding on them, and benefit on plant seed dispersal (Fukui, 1995; Corlett, 1998b; Kitamura *et al*, 2002; del Hoyo *et al*, 2005; Sankamethawee *et al.*, 2011; Kerdkaew *et al*, 2014). In addition, according to some studies located in South East Asia, bulbuls are the dominant bird which assemblage on fruiting plants in pristine forests (Sankamethawee *et al.*, 2011) and also early successional habitats (Sritongchuay *et al.*). Moreover, different bulbul species may provide different patterns on plant seed dispersal, for example fruit removal rate, seed shadow and seed deposition site, as they have different home range and habitat selection characteristics (Kerdkaew *et al*, unpublished). However, those aspects of bulbul seed dispersal studies are still limited in South East Asia in term of seed dispersal as there are few research done (see Khamcha *et al*, in press). In this study, we investigated seed dispersal of pioneer tree, (*Callicarpa arborea* Roxb.) by two common bulbul species. There were yellow-vented bulbul (*Pycnonotus goiavier*) and red-eyed bulbuls (*Pycnonotus brunneus*). We hypothesized that the seed dispersal of *C. arborea* provided by these two bulbuls in term of quantitative fruit removal, seed shadow and seed deposition site will be different as their different habitat preference.

Materials and methods

Study site

The research was carried out at an early successional forest patch within Khao Pra Bang Khram Wildlife Sanctuary (8°10' N and 98°80' E), Krabi, southern Thailand from November 2011 to October 2012. In the wildlife sanctuary, habitat structure is mainly lowland tropical forest, at elevation range from 25-100 m, varying from primary evergreen to seasonal forest, and mixed vegetation between hardwoods and bamboos is presented in this area (Maxwell, 2009). This protected area was mostly surrounded by oil palm and rubber plantations, and also several isolated forest patches. During the study period, it can be argued that there was wet season for almost month as monthly accumulative rainfall was higher than 60 mm. and the climate was tropical rainforest type under the Köppen-Geiger system (Peel *et al*, 2007). However, a tropical depression unexpected appeared in southern Thailand in January so that the accumulative rainfall of this month was much higher than usual (Thai Meteorological Department). The annual rainfall in 2011 and 2012 were ca. 2,000 mm. The mean minimum temperature ranged from 19.5^{o}C in September and August to 20.8^{o}C in April, and the mean maximum temperature peaked in February (33.5^{o}C) while it was lowest in December (31.0^{o}C). (Fig. 1)

Vegetation in the study site is dominated by a grass, *Imperata cylindrica* and a small shrub, *Melastoma malabathricum* L. ssp. *malabathricum*. Major woody trees are *Eurya acuminata* DC. var. *acuminate*, *Callicarpa arborea* Roxb. var. *arborea*, *Vitex pinata* (Lour.) Will. and *Ficus hispida* L. f.. This early successional area is approximately 20 hectares surrounded by primary lowland evergreen forest while in the east side the area is separated from the rubber plantation by a small patch of primary forest (200 m patch width). There is a small stream run along the west of this area. Previously, this forest patch was illegally converted to be oil palm and rubber plantations and was abandoned after law enforcement. In 2009 and years after, reforestation programmes using the native trees have been launched by the Forest Restoration Research Unit (Chaing Mai University) and the wildlife sanctuary. However, this area was burnt every year by human-initiated fire, and the reforestation programme appears to be unsuccessful.

Study Species

Yellow-vented bulbul (*Pycnonotus goiavier personata*) widely distributes in South East Asia ranging from central and southern Thailand to Malaysia, Indonesia and the Philippines (del Hoyo *et al*, 2005). It is commonly found in open habitats, and one of the most common birds in cultivated areas (del Hoyo *et al*, 2005). It is an omnivorous species that mainly feed on various species of fruiting plants (del Hoyo *et al*, 2005; Kerdkaew *et al*, 2014). Its breeding season started in February and peaked in May, and it usually lays 2 eggs, sometime up to 5 eggs in nest. Nests sites are vary, ranging from low shrubs to tall trees (del Hoyo *et al*, 2005 ; Wee, 2009).

Red-eyed bulbul (*P. brunneus*) is also a common resident bird to southern Thailand, Malaysia, and Indonesia (del Hoyo *et al*, 2005). Its body size is similar to the Yellow vented bulbul, 24-37 g, (del Hoyo *et al*, 2005). It is usually found in variety of habitats including evergreen, deciduous, and secondary forest (del Hoyo *et al*, 2005). In addition, it is also found in the oil palm and rubber plantation (del Hoyo *et al*, 2005). Similar to Yellow-vented bulbul, it is an omnivore. Its breeding season starts in March and end in May (Kobkhet, 2001). Female lays 2-3 pink with purple spot and brown line eggs. Both male and female create the nest and rear off springs together (Kobkhet, 2001).

Callicarpa arborea Roxb. (Family :Lamiaceae) is a small tree, up to 10 m high. It widely distributes in lowland evergreen forest and disturbed area (Leeratiwong *et al*, 2009 ; Maxwell, 2009). Its fruit is a small (2 mm. diameter) berry, and become dark violet when it ripe. *C. arborea* Roxb. produces flowers and fruits all year round (Leeratiwong *et al*, 2009).Within a study area, *C. arborea*. accounts for the most common woody plant, and bulbuls, (Family : Pycnonotidae) is a major visitor of this species (Srithongchuay *et al*, submitted).

Reproductive phenology of *Callicarpa arborea* Roxb.var. *arborea*

All mature trees (DBH > 10 cm.) of *C. arborea* were tagged and mapped?.The phenology observation started in November 2011 to October 2012. In each month, ten trees were randomly monitored with binoculars, and the stage of reproductive phenology (flower buds, open flowers, immature fruits and mature fruits) was scored by applying the crown density method (Koelmeyer, 1959). The scoring criteria of this method use a numeric scale of 0-4 which 0 indicates that there are no fruit or flower present, where 1, 2, 3 and 4 represent for 25%, 50%, 75% and higher than 75% of reproductive organs respectively. Values between 0 and 1 were used for scoring if the intensity of reproductive part was lower than quarter in comparison with maximum intensity.

Fruit removal observations

One to two trees which produced ripe fruits at least 5% were randomly selected to monitor every month from November 2011 to October 2012. In total, twenty *C. arborea* trees were observed between 0700h and 1700h with a maximum of twenty hours observation per tree. The observation sessions were categorized to morning (0700h – 0930h), late morning (0930h – 1200h), afternoon (1200h – 1430h) and late afternoon (1430h – 1700h). All visiting birds were identified using The Bird Guide of Thailand (Nabhitabata *et al*, 2008), and the number of fruit removal and time spent on fruiting trees were recorded. Fruit removal is defined as the number of fruits swallowed and moved away by birds.

Movement patterns of two Bulbuls

P. brunneus and *P. goiavier* were captured by mist nets in the field site two days a month from November 2011 to December 2012. Six mist nets (2.5 x 9 m^2) in total were set in the central of grassland, transition zone and run stream where birds used for bathing from 0700h to 1700h. All mist nets were monitored every ten minutes to check for trapped birds if birds were trapped, all birds were removed from mist nets and put in 10 x 20 cm^2 cloth bag preparing for weighing and attaching radio transmitter. Sex of captured birds cannot identify as there were no sexual dimorphism of these bulbuls. Birds were tagged with 1.2 g radio transmitters (BD-2, Holohil Systems, Canada) using leg loop harness with elastic ring (Rappole and Tipton, 1991), and aluminum leg band were attached to each bird to ensure that we would not track the same individual more than one time. This transmitter attachment technique allows the transmitter to fall off after a month when the elastic ring is broken. The transmitter weight is lower than 5% of bird weight (23-35 g) to minimize negative effects on bird movement (Cochran, 1980). Tagged birds were followed for three to eight days in total both in the morning (0700h – 1000h) and afternoon (1400h – 1700h). The movement of each tagged bird including location, time duration per movement and habitat use was recorded. Locations of tagged bird were recorded with GPS (Garmin GPS Map 60CSx, ± 5 m. accuracy) using homing with Receiver (Wildlife Materials TRX-48S) and a hand-held 3-element Yagi antenna (White and Garrott, 1990). The signal strength of transmitters was calibrated for the known distances before attaching to the birds, so the distance between observer and bird could be estimated accurately in cases that bird cannot be seen. Moreover, if bird was seen, range finder was used to estimate distance from bird to observer. As birds were followed continuously, we assumed that the error of fixes location is lower than 10 m. The movement distances of bird were calculated later using the Animal Movement Extension (Hooge *et al*, 2000) in the program ArcView GIS 3.2 (ESRI, Inc.).

Gut passage time

Mature seven yellow-vented bulbuls were trapped in an urban area, Hatyai, Songkhla province, and three red-eyed bulbuls were trapped in old-growth rubber plantation and secondary forest in Natawee district, Songkhla province by mist nets. Because these two species of bulbuls are commonly found throughout the southern Thailand, we assume that there are no effects of bird locality on the gut passage time. All captured birds were weighed, measured and then transferred to the Prince of Songkla University for conducting gut passage experiment. Birds were individually put in 40 x 40 x 60 cm cages and maintained on seedless banana and water one day before the experiment begin to make sure there were no seeds left in birds' gut. Birds ingested fifty *C. arborea* fruits. Water was provided *ad libitum*. White plain papers were spread on the floor of cage to ensure that seeds dropping on the floor could be recorded clearly. Birds were recorded continuously by using a high definition web camera (Microsoft VX3000) which connected directly to a computer. The recording was started before bird fed on fruits and lasted until the bird consumed the last fruit and defecated the last seed. The number of fruits ingestion, time when the last seed were deposited, and the gut passage time of each dropping were recorded.

Seed shadow and seed site deposition

Seed shadow of *C. arborea* was estimated by modeling of movement and gut passage time of *P. goiavier* and *P. brunneus* fallowing Murray (1988). Movements of bulbuls which occurred after feeding on *C. arborea* were selected to calculate the probability of deposition in each distance interval. The distance intervals were classified into 10 meters per level. The criteria were based on the movement patterns of each bird species which recorded in the different period. To perform seed shadow estimation, the movement patterns and gut passage time of two bulbul species were categorized to five minute intervals. The probability of each movement range were multiplied by the probability of seed defecation which examined by the gut passage experiment. Then the probabilities of seed deposition were summed in all time intervals of each distance interval, so the probabilities of seed deposition were drawn in distribution chart.

The defecation proportion in each habitat of *P. goiavier* and *P. brunneus* were calculated by multiplying the accumulative displacement distances from the parent *C. arborea* in different habitats with the gut passage time interval. Habitats were separated to four types including open grassland, transition zone, forest interior and rubber plantation. Transition zone was the area that started from the edge to 50 meters into the forest, and primary forest connected to the transition zone? onwards. Finally, the proportion of defecation of each habitat type was summed in all distance intervals to show the proportion of seed dropping in all habitat types, and it was transformed to the number of defecation in each habitat type by multiplying the total number of all displacement point generated by 2 bulbuls.

Statistical analysis

The differences in *C. arborea* fruit removal in each period of day by two bulbuls and the patterns of deposition number in different habitats provided by *P. goiavier* and *P. brunneus* were performed by Chi-square tests. Independent sample t-test or one-way ANOVA were used to test the difference of feeding time, number of fruit removal on *C. arborea* by two bulbuls in each period, the different of gut passage time and the difference of displacement in which equal to maximum gut passage time after feeding on *C. arborea* trees of two bulbuls were tested also. Pearson correlation was used to test the relationship between ripe fruit phenology of *C. arborea* and mean fruit removal per hour by *P. goiavier* and *P. brunneus*, and between ripe fruit phenology of *C. arborea* and mean time spent on *C. arborea* tree by this 2 bulbuls. If data did not meet the requirement of parametric test, (lack of homogeneity of variance or a non-normal distribution, Man-Whitney U, Kruskal-Wallis test or Spearman Rank Correlation were used instead of those analysis. All values were reported in mean ± SD. All statistical analyses were carried out in SPSS 15.0

Results

Focal tree observations

During 440 hours of observation of 20 trees, we recorded 887 bird visitations, and 4,705 fruits removed number. We recorded 33 bird species visiting *C. arborea*, of which 19 species fed on fruits. Bulbuls were the major group that visited and fed on *C. arborea* fruits, comprising of 71.6% and 92.3% respectively. Four species of bulbul namely, *P. goiavier*, *P. atriceps*, *P. brunneus* and *P. finlaysoni* made-up a high proportion of visits, 27.5%, 18.4%, 9.0% and 7.0% respectively. However, the top three bird species which contributed highest fruit removal rate were *P. goiavier*, *P. brunneus* and *P. f inlaysoni*, comprising of 41.4%, 18.0% and 12.2% respectively (Table 1). Mean feeding time of *P. brunneus* and *P. goiavier* were 2.5 ± 1.45 minutes and 2.2 ± 1.36 minutes, respective which was not signficantly different (Mann-

Whitney U-test: U = 3610, P = 0.25). There was no significantly difference of the feeding time of *P. brunneus* in four different sessions (Kruskal-Wallis test: df = 3, H = 1.337, P = 0.720), and feeding time did not differ in *P. goiavier* also (Kruskal-Wallis test: df = 3, H = 3.313, P = 0.346). Mean fruit removals of *P. brunneus* and *P. goiavier* were 13.9 ± 7.7 fruits/visit and 14.8 ± 8.14 fruits/visit respectively, which was not significantly different (Mann-Whitney U-test: U = 3752.5, P = 0.448). In *P. brunneus*, fruit were mostly removed in the morning (0700-0930) and in the late afternoon (1430 – 1700) around 57.3% and 23.0% respectively. This trend was also similar in *P. goiavier* that fruits were highly consumed in the morning and late afternoon session, comprising of 44.4% and 30.70% respectively. Moreover, there was not significant difference in temporal feeding pattern of two bulbuls in four different sessions (χ^2= 4.7, df =3, P = 0.195). (Fig.2) Overall, mean fruit removal per hour of *P. brunneus* and *P. goiavier* were 1.9 ± 2.53 fruits/hour and 4.4 ± 4.83 fruits/hour, respectively, and there was significantly different of fruit removal per hour by this two bulbuls (Mann-Whitney U-test: U = 595.5, P = 0.002). There was a positive correlation between monthly ripe fruit phenological score and number of fruit removal per hour of *P. brunneus* (r_s = 0.579, P = 0.024) and *P. goiavier* (r_s = 0.595, P = 0.021) (Fig.3). However, There was no correlation, but positive trend between monthly ripe fruit phonological score and time spent on *C. arborea* tree of *P. brunneus* (r_s = 0.424, P = 0.085) and *P. goiavier* (r_s = 0.319, P = 0.156)

Gut passage experiment of *P. brunneus* and *P. goiavier*

We recorded 40 and 60 droppings of 3 *P. brunneus* and 7 *P. goiavier* individuals. The mean gut passage time of *P. brunneus* was 22.9 ± 8.77 min., ranging from 4.9 min to 45.9 min, and of *P. goiavier* was 23.2 ± 11.08 min., ranging from 3.8 min to 56.33 min. (Fig 4). There was no significant difference between gut passage time of two bird species (Mann-Whitney U-test: U = 1159.5, P = 0.776). The mean first and last seed defecation time of *P. brunneus* was 14.4±10.06 min and 37.3 ± 11.34 min. respectively, and of *P. goiavier* was 11.1± 4.23 min. and 34.0 ± 15.18 min. respectively. The mean first and last seed did not differ among two bulbuls (Mann-Whitney U-test: U = 8, P = 0.569, Mann-Whitney U-test: U = 9, P = 0.732, respectively). Overall, the gut passage time of *P. brunneus* and *P. goiavier* were not different.

Seed shadow estimation and seed site deposition

We used 29 and 113 actual movements after feeding on *C. arborea* which equal or longer than the maximum last seed passage time observed from *P. brunneus* (N = 6) and *P. goiavier* (N = 10). Seed dispersal distance of *C. arborea* tree produced by the *P. brunneus* and *P. goiavier* range from 0 to 310 m. and 0 to 288 m. respectively. According to the seed shadow estimation provided by *P. brunneus*, we found that majority of seeds (57.8%) were deposited within 40-120 m which around 30% of all faeces were dropped in 80-120 m. However, in *P. goiavier*, the majority of seed (67.5%) were distributed from parent trees within 20-100 m of which 40.4% were defecated in 20-60 m from parent tree (Fig. 5). Based on displacement movement into different habitat, *P. brunneus* mostly dropped seed in transition zone (55.0%), followed by grassland (39.2%) and forest interior (5.8%) respectively. In contrast, *P. goiavier* mostly defecated in grassland (97.5%), and rarely dispersed seeds in transition zone (2.1%) and rubber plantation (0.4%) respectively. There were significant differences of defecation percentage in different habitats derived from seed shadow estimation between 2 bulbuls (Chi-square: χ^2= 474.27, df =2, P < 0.0001) (Fig. 6).

Discussion

Our result indicate that *P. brunneus* and *P. goiavier* provided different seed dispersal services, including fruit removal rate, seed shadow and seed deposition site, of an early successional tree, *C. arborea*.

Overall, bulbuls contributed the highest visitation on *C. arborea* in tropical grassland habitat. Similarly, bulbul is the major bird group visiting a fig (*Ficus caulocarpa*) in lowland dipterocarp forest, Maliau basin, Sabah, Malaysia (Sreeka et al. 2010). Moreover, other studies in tropical deciduous forest of central India (Mishra et al., 2007) and in African montane forest, Rwanda (Graham et al., 1995), also reported that bulbuls were the important seed disperser as they visited tree frequently. We found that bulbuls not only the main group that visit *C. arborea* trees, they also made the highest fruit removal rate. This phenomenon is comparable with the study of Mishra et al., (2007) which found that the red-vented bulbul (*Pycnonotus cafer*) made the highest visit and contributes to the highest fruit removal rate of *Ziziphus oenophelia*. Thus, this bulbul was a major seed dispersal agent of *Z. oenophelia*.

In this study, the two major visitors and fruit removal of *C. arborea* were *P. goiavier* and *P. brunneus*. All in all, both bulbuls represent similar feeding time and number of fruit remove per visit. Moreover, the fruit removal amount per hour provided by two bulbuls was positively correlated with the phenological score of ripe fruit production but not correlated with time spent on *C. arborea* trees. In general, the more ripen fruits on trees, the more fruit removal rate. This may be caused by their feeding behavior and body size that were not different (Khobkhet, 2001). However, *P. goiavier* contributed the highest visitation and fruit removal rate, so it can be argued that *P. goiavier* is more effective seed disperser than *P. brunneus* in term of quantity seed dispersal as *P. goiavier* can disperse seed number ca. two times higher than *P. brunneus.* Moreover, habitat preference of these bulbuls was different. *P. goiavier* always use open area; however, *P. brunneus* mostly present in edge or high dense of vegetation area (Kerdkaew *et al*, unpublished data). It is possible that *P. brunneus* sometime forage in the open area, but mostly strict to the dense vegetation area along edge area or pristine forest. Thus, by the different of habitat use, *P. goiavier* present more frequent than *P. brunneus* on *C. arborea* tree which always found in the open area.

The pattern of temporal fruit removal of two bulbuls is similar, and fruits were mostly removed in the morning and late afternoon as general foraging activity of bird are dominant at those period (Bibby et al, 1992). The reasons behind this event may be new ripe fruits were produced and abundant in the morning (Sreeka et al, 2010). In addition, birds always highly active in the morning as they need energy after long resting at night. Therefore, a great number of fruits were consumed to uptake nutrient and energy in the morning. In the late afternoon also, birds becomes more active comparing to the late morning and afternoon which the sunlight are strong and high temperature. During this time, birds perhaps increase feeding activity preparing in order to reserve energy for the long resting period at night. Therefore, the fruit removal pattern by these birds was notably higher in the early morning and late afternoon.

Our study suggested that around 90% of *C. arborea* seeds are likely to be dispersed far from canopy of parent tree by these two bulbuls. In this case bulbuls can carry and deposit seeds up to 310 m which often in their home range. Similarly, bulbuls were reported as a short distance seed dispersers which most of seeds they hold in gut were usually dropped within 100 m around the parent tree (Weir and Corlett, 2007 ; Green et al, 2009 ; Khamcha et al, in press), and within their home range, approximately 300 m (Fukui, 1995). The seed dispersal distances produced by *P. goiavier* which most seeds were deposited in 20-60 m far from parent tree were notably lower than of *P. brunneus* that seeds could be mostly distributed to 60-120 m around parent tree. This phenomenon results from the difference in habitat use of these bulbuls. *P. goiavier* is the open area lover (del Hoyo *et al*., 2005). It mostly forages on the grassland as its overall diet were plant species found in open area (Kerdkaew *et al*, 2014), and this bird rarely moves across habitat. In contrast, *P. brunneus* prefer dense vegetation along transition zone and forest interior surrounding the grassland (Kerdkaew, unpublished). *P. brunneus* sometimes came out from those surrounding areas to feed on the most dominant fruiting tree in the open area (>100 plants), and *C. arborea* trees producing ripe fruit all year round (Leeratiwong et al, 2009) and easy to access by many frugivores. *C. arborea* becomes the important food resource for bulbuls in this area as found in their diet as the highest importance food resource (Kerdkaew *et al*, 2014). After feeding on *C. arborea* fruits, *P. brunneus* usually moved back to early successional forest and forest interior in vicinity of grassland, so these movements may increase dispersal distance of *C. arborea* generated by this bird. Also, we were able to observe pairs and flocks of *P. brunneus* fly across grassland habitat, so these movement characteristics may alter the seed shadow pattern produced by these birds as the diameter of grassland is ca. 500 m. Red-whiskered bulbuls (*Pycnonotus jocosus*), which are similar in size (24-37 g.) with *P. brunneus* and *P. goiavier*, can move in a long distance for more than 1.3 km., but this rarely occurred (Weir and Corlett, 2007). Moreover, long movements by bird could be occurred when it follows preferred food plants, as finding on the black-and-white bulbul (Lambert, 1989). Therefore, it is possible that bulbuls can cause long distance seed dispersal at some point, but in this study we did not detect the long distance movement. However, in this study, the seed shadow pattern provided by *P. brunneus* may be not well represent as relatively low observation numbers of actual movement patterns after leaving *C. arborea* canopy.

Although a large number of seeds were likely dispersed to other areas, some seeds were probably deposited under other *C. arborea* trees which can cause the negative effect on those seeds, such as seed predation. However, the total seed number found under *C. arborea* and *M. malabathricum* which examined from bird droppings was around 1,400 seeds in this area for one year observation (Sritongchuay *et al*, submitted) so that, with the relative low number of seed found under those isolated plants, most seeds were less possible to drop under other *C. arborea* trees.

By the difference in habitat use, the site depositions of *C. arborea* seeds provided by these two birds were notably different. Almost *C. arborea* seeds carried by this bird are likely dropped on the grassland which is the main habitat type that *P. goiavier* use. There was little number of seeds dispersed to other habitat types, such as edge area and rubber plantation. The reason for its open area preference of *P. goiavier* might be the main food it consumed were the open area plant, for example, *Melastoma malabathricum* and *C. arborea* which were superabundant in this area. These plants took part around 70% of overall diet of *P. goiavier* (Kerdkaew *et al*, 2014). As its main food resource nourishment in the open grassland, *P. goiavier* still forages on this area with no pressure on food resource limitation. In contrast, seeds of *C. arborea* were mainly distributed by *P. brunneus* to edge area. As mentioned before, *P. brunneus* prefer the high dense vegetation area, such as edge, secondary forest, primary forest, or even old growth plantation area (Khobket, 2001; del Hoyo *et al*., 2005).

This study found out that seed dispersal effectiveness of *C. arborea* serviced by two common bulbuls was noticeably different. Certainly, *P. goiavier* provided higher quantitative and qualitative seed dispersal as they contributed in highest fruit removal rate, dispersed seeds far away from parent plants and dropped most seeds on suitable site in comparison with *P. brunneus*. Therefore, this bird is the effective seed disperser of *C. arborea* and/or other early successional plants as they are a generalist frugivore which feed on many plant in this area (Kerdkaew *et al*, 2014). Moreover, seed dispersal distances may deal with many factors (Murray, 1988; Westcott and Graham, 2000). For bulbuls, the behavior and status of them, such as breeding and incubating status, daily periods and group size which can increase or decrease the displacement of seeds distributed from mother trees (Khamcha *et al*, in press). However, in this study we could not investigated on the influence of those factors on seed dispersal because of low sample size of actual bird movements after feeding on *C. arborea* trees. Further study should focus on those social structure and behavior to reveal the role of bulbuls on seed dispersal of early successional plant to be more completed.

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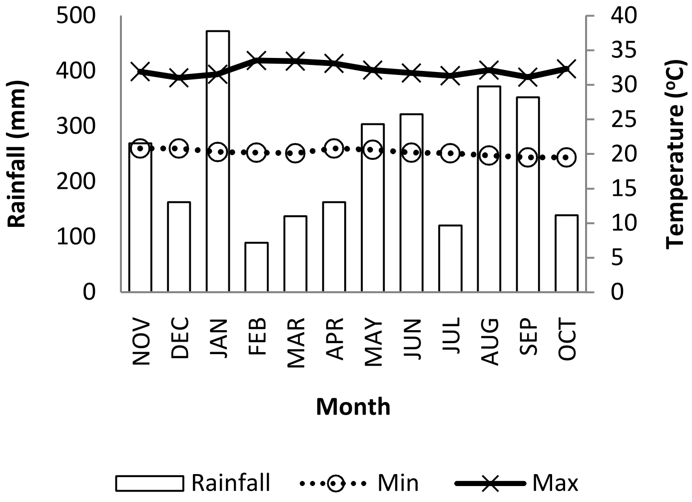

Figure 1. Monthly rainfall (mm), average monthly minimum and maximum temperature (^{o}C) at Krabi Meteorogical Center during November 2011 to December 2012. This station is around 30 km from the study site.

Table 1 Proportion of visitation (N = 877) and fruit removal (N = 4,705) by 33 bird species in *C. arborea* canopy

Species	Visitation (%)	Fruit removal (%)
Family Pycnonotidae	**71.61**	**92.35**
Pycnonotus goiavier	27.48	41.40
Pycnonotus atriceps	18.36	9.05
Pycnonotus brunneus	9.01	17.98
Pycnonotus finlaysoni	6.96	12.24
Pycnonotus simplex	2.28	4.00
Pycnonotus flaviventris	2.05	1.98
Pycnonotus plumosus	2.05	2.10
Pycnonotus erythropthalmos	1.14	0.83
Alophoixus ochraceus	0.80	1.02
Pycnonotus blanfordi	0.80	1.68
Bulbuls (Unknown spp.)	0.68	0.06

Family Dicaeidae	**18.70**	**4.40**
Dicaeum cruentatum	10.15	1.17
Dicaeum trigonostigma	7.98	3.23
Prionochilus percussus	0.46	-
Flowerpecker (Unknown spp.)	0.11	-
Other Species	**9.68**	**3.25**
Arachnothera longirostra	1.83	0.04
Anthreptes malacensis	1.03	-
Nectarinia jugularis	0.80	-
Sunbird (Unknown spp.)	0.80	-
Lonchura striata	1.37	-
Treron vernans	0.57	0.89
Muscicapa dauurica	0.46	-
Cyornis tickelliae	0.11	-
Megalaima haemacephala	0.34	1.02
Megalaima lineate	0.11	0.45
Chloropsis cyanopogon	0.34	0.26
Chloropsis sonnerati	0.11	0.53
Loriculus vernalis	0.34	0.06
Orthrotomus atrogularis	0.34	-
Phaenicophaeus curvirostris	0.23	-
Lanius cristatus	0.23	-
Zosterops sp.	0.23	-
Halcyon smyrnensis	0.11	-
Aviceda leuphotes	0.11	-
Oriolus xanthonotus	0.11	-
Terpsiphone paradisi	0.11	-

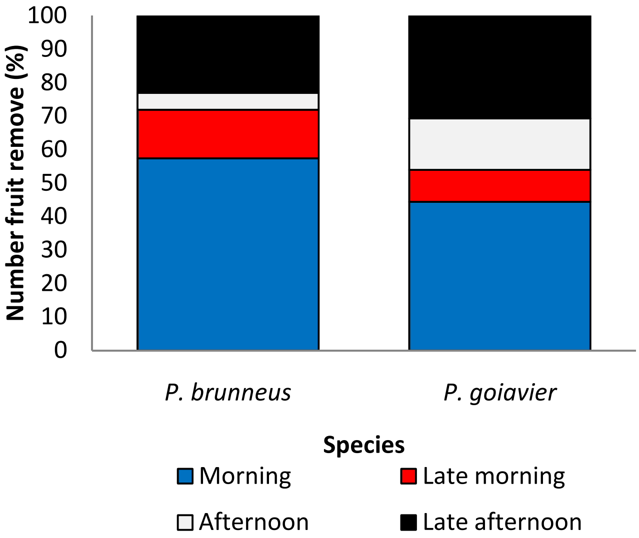

Figure 2 Fruit removal percentage of *P. brunneus* (N = 846) and *P. goiavier* (N = 1,948) in four different sessions which based on 440 hours observation of 20 *C. arborea* trees

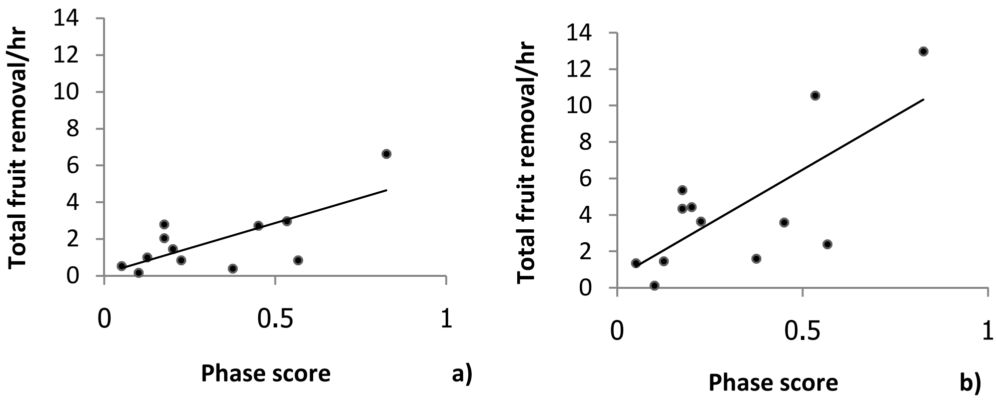

Figure 3 Relationship between total *C. arborea* fruit removal per hour by (a) *P. brunneus* (b) *P. goiavier* and monthly phenological score of *C. arborea* ripe fruit.

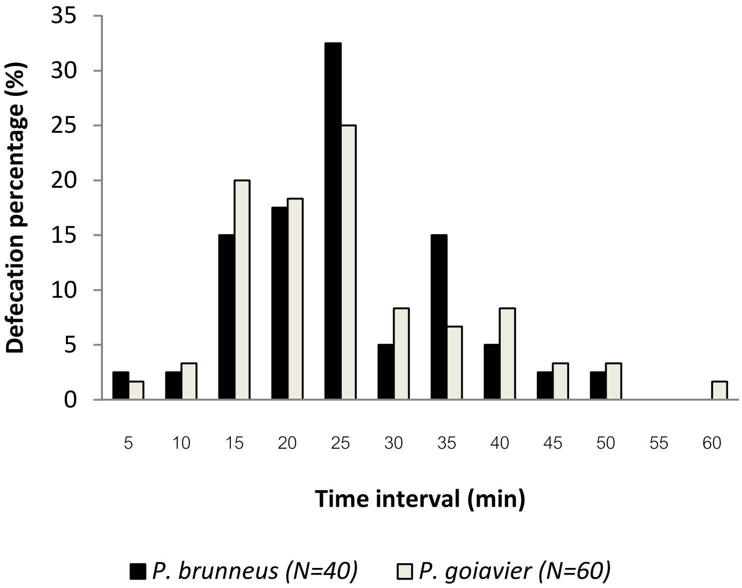

Figure 4 Distribution of gut passage time of *C. arborea* seeds produced by *P. brunneus* and *P. goiavier*.

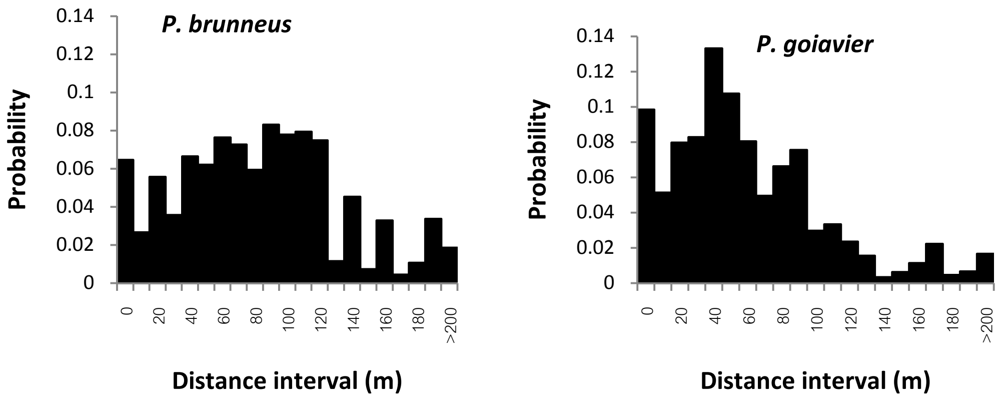

Figure 5 Seed shadow estimation of *C. arborea* seeds provided by *P. brunneus* and *P. goiavier* movement patterns after foraging in *C. arborea* trees.

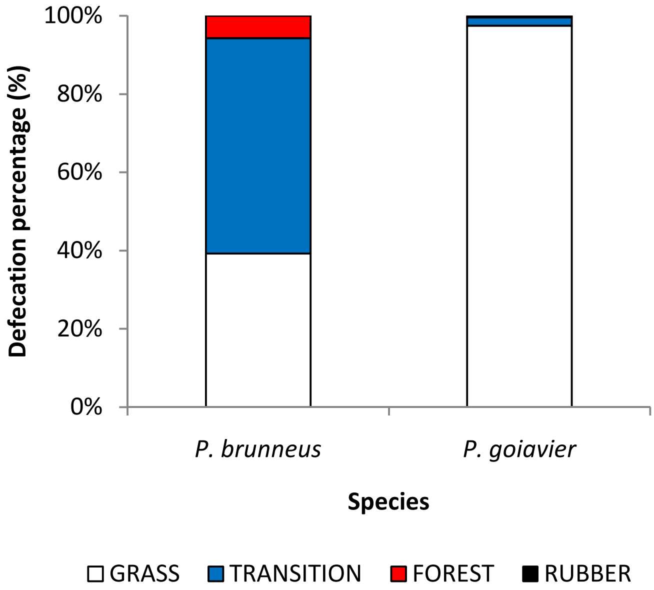

Figure 6. Defecation percentage in different habitats of *P. brunneus* (N = 187) and *P. goiavier* (N = 880) after feeding on *C. arborea* trees. Data were based on the multiplication of the probability of habitat type of each movement distance interval from *C. arborea* and gut passage time of the two bulbuls.