Agr. Nat. Resour. 53 (2019) 457–464

AGRICULTURE AND NATURAL RESOURCES

Journal homepage: http://anres.kasetsart.org

Research article

Utilization of fruit by frugivores in lower montane forest at Doi Suthep-Pui National Park, Chiang Mai province

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Article Info

Article history:
Received 28 March 2018
Revised 11 March 2019
Accepted 15 March 2019
Available online 31 October 2019

Keywords:
Diversity,
Frugivores,
Long-term ecological research,
Lower montane forest,
Seed disperser

Abstract

Utilization of fruit by frugivores is important for the natural recovery of forests. This study clarified the regeneration status and fruit utilization by frugivores in a 16 ha lower montane forest permanent plot in the Mae Sa-Kog Ma Biosphere Reserve. Fruit utilization was monitored using camera traps from May 2015 to April 2017. Of the 74 fruit bearing species (402 individuals/ha) 28 species were surveyed but only 8 of these provided fruit and of these, camera trapping detected frugivore activity on six species. The highest density species was *Castanopsis acuminatissima* (139 individuals/ha), followed by *C. armata* (33 individuals/ha) and *Helicia nilagirica* (23 individuals/ha), respectively. The diameter class distribution of fruit trees was described using a negative exponential form. Fourteen frugivore species utilizing the six fruiting species based on detection in 709 video clips. The most frequently utilized plant by frugivore species was *Mudhuca floribunda*, followed by *Musa acuminata*, *Ficus hirta*, *F. semicordata*, *C. acuminatissima* and *Schefflera* sp., respectively. In addition, *Musa acuminata*, *F. hirta* and *F. semicordata* provided fruits throughout the year and played an important role as frugivore food resources which strongly influenced the abundance and distribution which are known more generally as keystone species. In contrast, the fruits of *C. acuminatissima* and *Schefflera* sp. were eaten only by rodents and birds, respectively, indicating that fruit utilization varied among the fruiting species. This knowledge can inform structural restoration programs in which fruiting species can attract frugivores to increase the success of plant restoration.

Introduction

Tropical forest has high diversity of both flora and fauna (Brown, 2014). Tropical forest areas have been under threat due to land use changes due to conversion to agriculture (Elliott and Kuaruksa, 2008). Most of the tropical forest vegetation consists of fruit trees (Kimura, 2003) which are important food resources for humans and frugivores. The frugivores utilize the fruit because it has high levels of nutrients and energy (Wilson and Downs, 2012). However, deforestation and degradation of forest areas are the main causes of a reduction in the frugivore food supply and may lead to population decreases or extinction (Sekercioglu et al., 2004; Tylianakis, 2013; Dirzo et al., 2014).

Natural forest restoration is a mechanism to support ecosystem balancing, giving organisms the conditions necessary to exist. The main

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https://doi.org/10.34044/j.anres.2019.53.5.03

factor helping natural forest restoration is seed dispersal, which has many vectors, both abiotic and biotic such as wind, gravity, water and animals and especially mammals and birds, which are major seed dispersers (Van der Pijl, 1982; Stiles, 1989). Plants rely on frugivores to distribute seeds from parent trees to increase the chances of seedling survival (Janzen, 1970; Connell, 1971; Stiles, 1989; Carlo and Yang, 2011). Seed density is greater under parent trees, thus seed predators, especially insects and pathogens, tend to increase in numbers and destroy more seeds in high seed density areas than in low seed density areas (Stiles, 1989). Plants, in essence, have evolved characteristics to attract frugivores to disperse their seeds. When seeds fall onto new suitable sites, such as open sites in degraded forest or a gap in the forest, they can germinate and become established and replace mature trees that will eventually die. Furthermore, forest regeneration can also provide food resources for wildlife, especially frugivores. Forest disturbance has a negative effect on the ecological processes of plant regeneration, particularly seed dispersal (Neuschulz et al., 2016). Plant regeneration comprises a cycle of life stages from seeds to seedlings and adult plants (Wang and Smith, 2002). A decline in the number of frugivores that act as seed dispersers results in reduced seed removal, especially for large-seeded fruiting species (Markl et al., 2012; Kurten, 2013). These early processes in plant regeneration depend on mutualistic plant- animal interactions (Neuschulz et al., 2016). Natural forest regeneration accelerates the recovery of the forest ecosystem. In addition, some fruiting species are important to the ecosystem which play an important role as food resources for frugivores. Even though these fruiting species have low abundance, many frugivores utilize them and if all the fruiting species become extinct this would be expected to lead to extinction of the frugivores. These fruiting species are called keystone species (Peres, 2000; Kattan et al., 2013)

Montane forests (MF) maintain ecological processes and ecosystem services not only for people in mountainous areas, but also for populations in lowland areas where demands are high from population centers, agriculture and industry (Regato and Salman, 2008). The environmental factors in MF are mostly highly specific, particularly extreme climatic conditions such as temperature and precipitation (Marod and Kutintara, 2009); thus, the recovery of mountain ecosystems from disturbances is typically slow or occasional (Crausbay and Martin, 2016). MF in Doi Suthep-Pui National Park is also facing deforestation and the diversity of not only plants but also wildlife is being reduced based on land-use practices of both intensification and land abandonment (Asanok et al., 2012). Furthermore, a database containing the regeneration status of fruiting species can help to predict food resource availability and to manage any restoration program (Melese and Ayele, 2017). Fruiting species can provide a large number of smaller diameter trees from good regeneration to maintain food for frugivores. Therefore, it is useful to know which fruiting species are important for frugivores as this can be very helpful in implementing natural ecosystem restoration. However, there is limited reporting of the relationships between seed dispersers and fruit availability in montane forest. Thus, the objectives of this research focused on clarifying the regeneration status of fruiting species and detecting fruit utilization by frugivores in a permanent plot of lower montane forest (LMF) in Doi Suthep-Pui National Park.

Materials and Methods

Study area

The study was conducted in a16 ha permanent plot of LMF in the Mae Sa-Kog Ma Biosphere Reserve, Doi Suthep-Pui National Park, Chiang Mai province, Thailand. This area was designated as a Biosphere Reserve by UNESCO in 1977 (Vongkuna, 2005). The wet season occurs during May-October and the dry season during November-April. The mean temperature in the wet season is in the range 18.93–21.79°C and 14.79–22.35°C in the dry season (Pimrat, 2016). The lowest average rainfall is 10 mm in the dry season, whereas the mean rainfall in the wet season is 335.2 mm (Glomvinya, 2016). The 16 ha permanent plot was located in the Huai Kog Ma watershed (18°54’N and 98°54’E), approximately 65 ha (Fig. 1). The elevation range within the permanent plot was 1,250–1,540 m above mean sea level with a mean slope of 40% (Vongkuna, 2005)

Density of fruit trees in permanent plot

The 16 ha permanent plot was established in 2010 and divided into subplots (10 m × 10 m), resulting in 1,600 subplots. All trees with a diameter at breast height (DBH, at 1.3 m above ground) greater than 2 cm were tagged, measured and identified to the species level (Marod et al., 2015). Fruiting species utilized by frugivores were reviewed from reports by Simcharoen (1990), Boonkaaw et al. (2001), Kitamura et al. (2002), Kominami (2003), Sankamethawee et al. (2011), Siri (2013) and Saosoong, (2014) and also identified based on direct observation of frugivore activity during 2015–2016 in the current study in the permanent plot. Then, all recorded fruiting species were analyzed for tree density to quantify the food resource availability in the permanent plot using Equation 1 according to Curtis and McIntosh (1951):

$$\text{Density} = \text{(Number of individuals trees in all subplots) / (Number of subplots)} \quad (1)$$

In addition, the diameter class distributions of fruit tree species were also analyzed to detect their regeneration processes. The DBH measurements of fruiting species were divided into 12 classes (DBH <4.5 cm and then every 10 cm up to DBH > 105.4). The diameter class distribution had two patterns: 1) exponential or J-shaped indicating that the lower frequencies of trees were in the low diameter classes with a gradual increase toward the higher classes; and 2) a negative exponential or reverse J-shaped pattern indicating that the higher frequencies of trees were in the low diameter classes with a gradual decrease toward the higher classes (Melese and Ayele, 2017). A distribution with a negative exponential pattern indicates the species can regenerate and provide fruit for frugivores in the future.

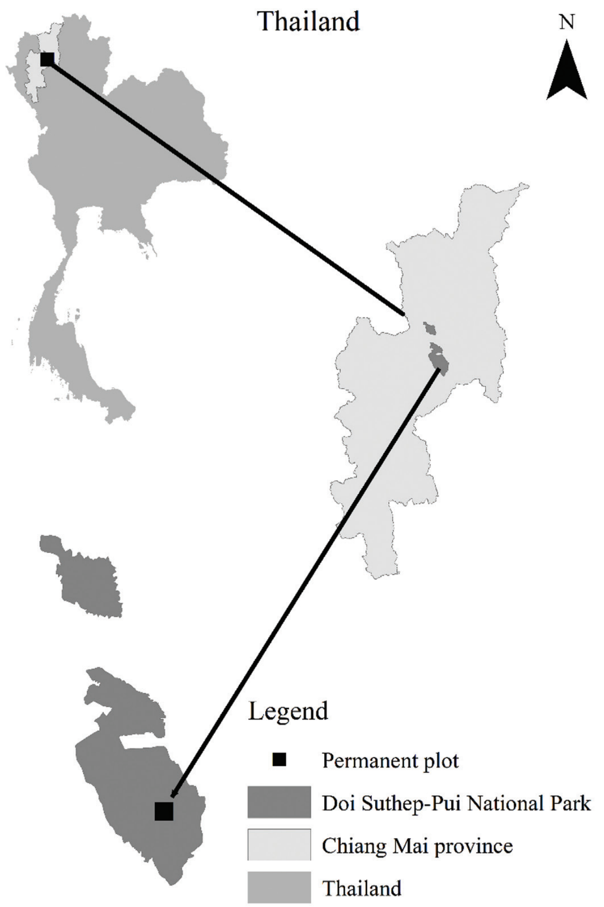

Fig. 1 Study site in lower montane forest of Doi Suthep–Pui National Park.

Fruit utilization by frugivores

Based on the literature review and the surveyed fruiting species utilized by frugivores in the permanent plot, 28 fruiting species were selected that represented each family and were abundant in the permanent plot. These fruiting species were monitored using binoculars during the fruiting period once a month from May 2015 to April 2017 (Table 1) and eight species provided many fruits and frugivores. Then, camera traps were set up (tree trunk, branch or ground due to fallen fruits) for at least three trees per selected fruiting species to record frugivore activity (Yasuda, et al., 2005; Suzuki et al., 2007). The height of lower branches where frugivore activity was recorded was not more than 10 m. The camera trap was placed about 2 m away from fruits (Suzuki et al., 2007), to detect and monitor frugivores activity (Fig.2). All camera traps were programmed using video mode to record on activation 30 s per session and the date and time. The camera traps were checked and their batteries renewed and memory cards replaced every month. The monitoring period using the camera traps continued until all of the fruit had rotted or been dispersed.

Table 1 Potential fruit species and those surveyed using camera traps in study area

Botanical name	Family	Camera trap established
Saurauia roxburghii	Actinidiaceae	No
Choerospondias axillaris	Anacardiaceae	Yes
Rhus succedanea	Anacardiaceae	No
Schefflera sp.	Araliaceae	Yes
Canarium euphyllum	Burseraceae	No
Protium serratum	Burseraceae	No
Mastixia pentandra	Cornaceae	No
Diospyros glandulosa	Ebenaceae	No
Elaeocarpus floribundus	Elaeocarpaceae	No
Baccaurea ramiflora	Euphorbiaceae	No
Bischofia javanica	Euphorbiaceae	No
Castanopsis acuminatissima	Fagaceae	Yes
Garcinia speciosa	Guttiferae	Yes
Apodytes dimidiata	Icacinaceae	No
Beilschmiedia gammieana	Lauraceae	No
Cinnamomum iners	Lauraceae	No
Litsea pierrei	Lauraceae	No
Phoebe paniculata	Lauraceae	No
Melia azedarach	Meliaceae	Yes
Artocarpus nitidus	Moraceae	No
Ficus semicordata	Moraceae	Yes
Musa acuminata	Musaceae	Yes
Syzygium tetragonum	Myrtaceae	No
Prunus arborea	Rosaceae	No
Acronychia pedunculata	Rutaceae	No
Sarcosperma arboreum	Sacospermataceae	No
Madhuca floribunda	Sapotaceae	Yes
Eurya acuminata	Theaceae	No

Species with no camera trap did not have any fruiting periods during the study

Fig. 2 Typical locations (circled) of camera traps related to fruit position: (A) *Musa acuminata*; (B) *Melia azedarach*

Frugivore species were identified from the camera trap video sessions. The numbers of fruits utilized by frugivores were counted based on the total recorded video footage. Then, the proportion of frugivores that utilized each fruit species was determined.

In addition, wild banana (*Musa acuminata*) and herbaceous plants, that flowered throughout the year were also included in the study.

Statistical analysis

Fruiting species and frugivores species were examined relationship by χ^2 test. The data were used in a χ^2 test is the numbers of fruits utilized by frugivores. Null hypothesis was that each fruit species attracted difference frugivore species. This analysis was done with R software version 3.5.3 (R Core Team, 2019).

Results and Discussion

Density of fruit trees

The permanent plot in LMF had 29,624 trees which could be divided into 211 species, 137 genera and 63 families. The fruiting species utilized by frugivores comprised 13,389 individual trees from 74 species 58 genera and 35 families. The families with the most fruiting species were the Fagaceae (6 species), Moraceae (6 species) and Lauraceae (6 species) followed by the Euphobiaceae (5 species), Clusiaceae (4 species) and Rutaceae (4 species) respectively (Fig. 3). These results corresponded to several reports in the other tropical mountain forest areas where the Fagaceae and Lauraceae were abundant in both the canopy and subcanopy layers (Sri-Ngernyuang et al., 2003; Kanzaki et al., 2004; Asanok, 2006; Sensit, 2009).

The density of all trees (DBH ≥4.5 cm) in the permanent plot was 968 individuals/ha while, the density of the fruiting species detected was 402 individuals/ha. *Castanopsis acuminatissima* had the highest density among fruit tree species, 139 individuals/ha, followed by *Castanopsis armata* (33 individuals/ha), *Helicia nilagirica* (23 individuals/ha), *Saurauia roxburghii* (20 individuals/ha) and *Acronychia pedunculata* (17 individuals/ha), respectively. The full list of species is shown in Table 2.

The diameter class distributions of all fruit trees (DBH ≥2 cm) were of the negative exponential form (Fig. 4). The higher frequencies were in the lower diameter classes and there was a gradual decrease toward the higher classes. This finding followed the same trend reported widely in previous research (Vannaprasert, 1985; Suksomut, 1987; Rattana, 1995; Pothitan, 1999; Asanok, 2006; Sensit, 2009). Fruit trees in the permanent plot could be regarded as in a state of dynamic equilibrium in which the saplings or juvenile trees can replace the mature trees in the forest (Ogawa, 1965; Melese and Ayele, 2017). This indicated they had high potential as a future source of frugivore food. Conversely, some fruiting species did not have negative exponential patterns. *Ficus hirta* had a stable number of individuals (6 individuals/class), whereas *Ficus semicordata* has a unimodal distribution (Fig. 5), which suggested population decline. In addition, frugivores can also help to disperse the seed to safe sites for seed germination which can increase the population of fruiting species (Corlett, 2014).

Fruit utilization by frugivores

Of the eight species monitored using the camera traps, only six provided fruits and were utilized by frugivores during the study, namely *Mudhuca floribunda*, *F. hirta*, *F. semicordata*, *C. acuminatissima, Schefflera* sp. and *Musa acuminata*. From the 29 camera traps (8,236 trap-nights or 197,664 trap-hours), 709 videos of utilization by frugivores were recorded. Fourteen frugivore species were identified, namely Pallas's squirrel (*Callosciurus erythraeus*), Red-cheeked squirrel (*Dremomys rufigensis*), Phayre's flying squirrel (*Hylopetes phayrei*), Burmese striped squirrel (*Tamiops mcclellandi*), Northern treeshrew (*Tupaia belangeri*), Common palm civet (*Paradoxurus hermaphroditus*), Masked palm civet (*Paguma larvata*), Northern Pig-tailed macaque (*Macaca leonina*), Black-crested bulbul (*Pycnonotus flaviventris*), Mountain bulbul (*Ixos mcclellandii*), Puff-throated bulbul (*Alophoixus pallidus*) and Ashy bulbul (*Hemixos flavala*) as well as an unidentified rat and bat. These frugivores could be divided into two groups: mammals and birds. The mammals utilized almost all fruit plant species, excluding the *Schefflera* sp. which was the only species utilized by birds.

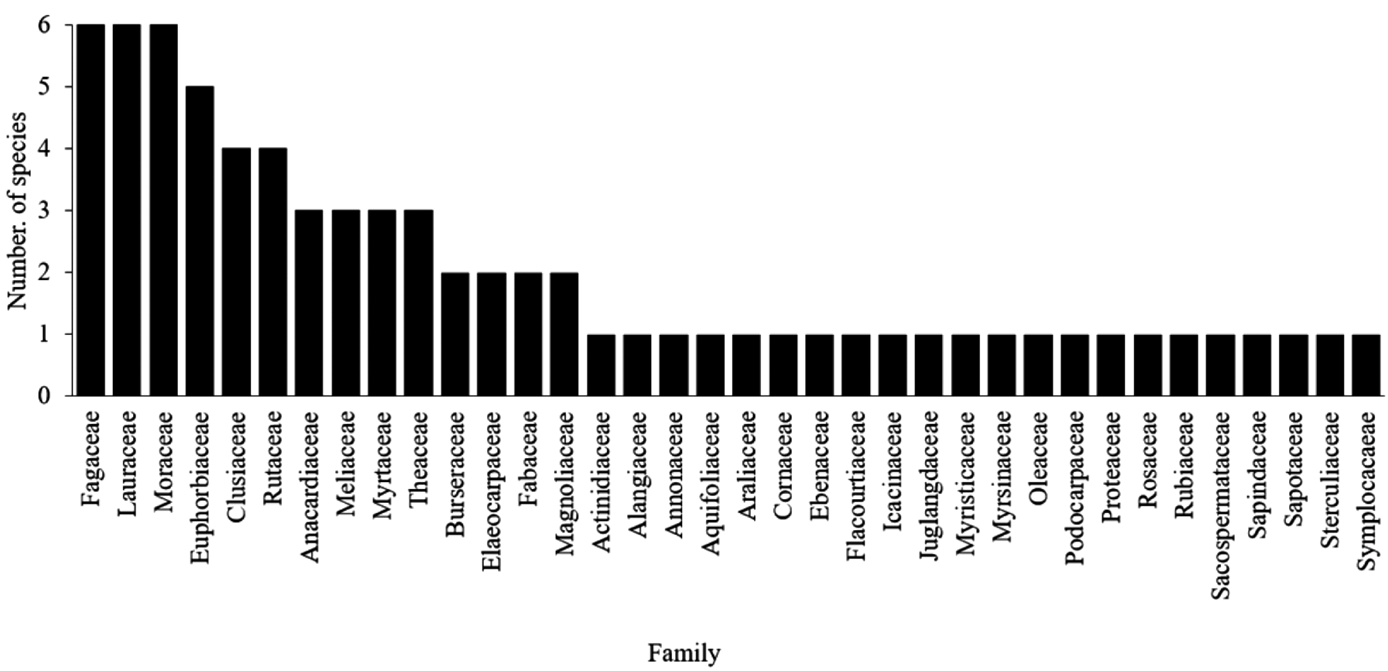

Fig. 3 Numbers of fruiting species based on family in the study area

Table 2 Fruit tree species density in study area

Species	Density (individuals/ha)	Species	Density (individuals/ha)
Castanopsis acuminatissima	138.69	*Schefflera* sp.	2.88
Castanopsis armata	32.75	*Aglaia lawii*	2.69
Helicia nilagirica	22.88	*Lithocarpus thomsonii*	2.25
Saurauia roxburghii	20.19	*Beilschmiedia gammieana*	2.19
Acronychia pedunculata	17.19	*Maesaramentacea*	2.19
Castanopsis tribuloides	15.06	*Mallotus paniculatus*	1.94
Apodytes dimidiata	12.75	*Bischofia javanica*	1.81
Lithocarpus truncatus	12.44	*Erythrinasubumbrans*	1.75
Michelia baillonii	9.31	*Rhus succedanea*	1.75
Pyrenaria diospyricarpa	9.19	*Pterospermum grandiflorum*	1.69
Eurya acuminata	8.94	*Mischocarpus pentapetalus*	1.56
Sarcosperma arboreum	8.75	*Ficus semicordata*	1.56
Manglietia garrettii	8.13	*Canthium glabrum*	1.44
Syzygium tetragonum	7.19	*Garcinia speciosa*	1.31
Canarium euphyllum	6.69	*Symplocos cochinchinensis*	1.25
Choerospondias axillaris	6.56	*Ternstroemia gymnanthera*	1.19
Garcinia thorelii	5.88	*Protium serratum*	1.13
Phoebe paniculata	5.81	*Micromelum minutum*	1.00
Syzygium claviflorum	5.81	*Podocarpus neriifolius*	0.88
Diospyros glandulosa	5.75	*Macaranga denticulata*	0.88
Engelhardtia spicata	5.38	*Chionanthus ramiflorus*	0.88
Prunus arborea	5.38	*Garcinia cowa*	0.88
Baccaurea ramiflora	5.19	*Decaspermum parviflorum*	0.81
Elaeocarpus floribundus	4.25	*Melia azedarach*	0.75
Lithocarpus dealbatus	4.19	*Mastixia pentandra*	0.75
Rhus succedanea	4.06	*Garcinia merguensis*	0.69
Sloanea sigun	4.06	*Artocarpus chaplasha*	0.63
Cinnamomum iners	3.88	*Balakata baccata*	0.56
Litsea pierrei	2.88	*Aglaia spectabilis*	0.56
Ficus curtipes	0.56	*Phoebe cathia*	0.25
Artocarpus nitidus	0.56	*Polyalthia viridis*	0.19
Antiari stoxicaria	0.44	*Clausenaex cavata*	0.19
Ilex umbellulata	0.38	*Alangium Kurzii*	0.13
Casearia grewiifolia	0.38	*Euodia meliaefolia*	0.13
Ficus hirta	0.38	*Madhuca floribunda*	0.13
Horsfieldia glabra	0.25	*Adenanthera pavonina*	0.06
Litsea glutinosa	0.25		

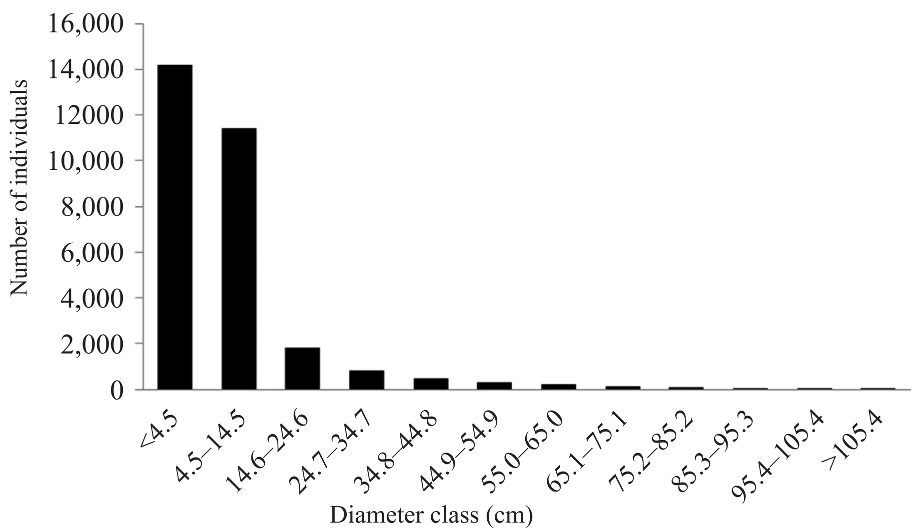

Fig. 4 Distribution by diameter class of all fruiting species found in the study area

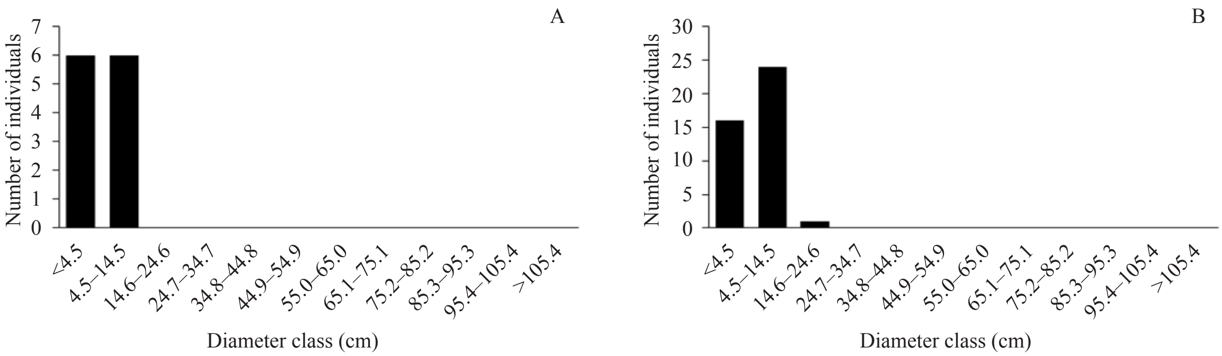

Fig. 5 Diameter class of fruiting species: (A) *Ficus hirta*; (B) *Ficus semicordata*

The fruiting species with the greatest number of frugivore species was *Mudhuca floribunda* (8 species), followed by *Musa acuminata* (7 species), *F. hirta* (7 species), *F. semicordata* (6 species), *C. acuminatissima* (5 species) and *Schefflera* sp. (4 species), respectively. The χ^2 analysis indicated the six fruiting species were consumed by significantly difference frugivore species except *F. hirta*. The numbers of frugivores utilizing fruits in each species and result of the χ^2 analysis are shown in Table 3. *Mudhuca floribunda*, wild banana and fig trees provide fruits throughout the year and are recognized as readily available fruit sources for frugivores (Shanahan et al., 2001; Marod et al., 2010). These fruiting species had a low density (Table 2) but had many frugivore species utilizing them, such as civets, bats, squirrels and treeshrews, indicating that these species can be considered as keystone because despite their low density in the permanent plot, they attracted many frugivores (Peres, 2000). In contrast, *C acuminatissima* and *Schefflera* sp. were specific species that attracted specific frugivores (only rodents and birds, respectively). The fruit selection by frugivores depends on the specific traits of the fruit for attracting specific frugivores to increase the chances of seed dispersion (Gautier-Hion et al., 1985; Stiles, 1989). *C. acuminatissima* has nuts covered by a thick cupule and spine and so was utilized only by rodents which have gnawing incisors and powerful jaw muscles, meaning they could destroy the mechanical protection of nuts (Corlett, 2017). However *Schefflera* sp., which has small fruits was selected by the bulbul (a bird species) perhaps because of the relationship between the size of the fruit and frugivore size. Wheelwright (1985), Jordano (1992) and Kitamura (2002) reported that frugivore capacity to consume fruits depended on the fruit size relative to the body size, gape width and mouth size of frugivores. Diamond (1973) studied fruit pigeons in New Guinea and reported that large birds consumed large fruit, whereas, small birds consumed small fruit. The camera traps detected that only a low number of frugivorous birds (4 species) utilized fruit in the permanent plot perhaps because of the limitation due to the position of the camera traps that were placed at 10 m and about 2 m apart from fruits and so may have missed activity at other heights. The monitoring of frugivores by camera traps was active 24 hr daily and most frugivores are nocturnal mammals that were detected during the night. In contrast, most frugivorous birds were detected during the day. The fruit selection by frugivores is important for seed dispersal and determines which fruiting species can exist in a specific location. At the same time, the fruits play a role as food resources for the frugivores. This interaction can help in forest restoration as fruiting

Table 3 Fruit utilization by frugivores

Fruit plants / Frugivore	*Mudhuca floribunda*	*Ficus hirta*	*Ficus semicordata*	*Musa accuminata*	*Castanopsis acuminatissima*	*Schefflera* sp.
Pallas's squirrel	71 (54.20%)	10 (14.49%)	11 (22.45%)	13 (11.30%)	13 (4.87%)	0 (0.00%)
Red-cheeked squirrel	10 (7.63%)	6 (8.70%)	13 (26.53%)	0 (0.00%)	219 (82.02%)	0 (0.00%)
Burmese striped squirrel	3 (2.29%)	9 (13.04%)	0 (0.00%)	2 (1.74%)	4 (1.50%)	0 (0.00%)
Phayre's flying squirrel	6 (4.58%)	5 (7.25%)	2 (4.08%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Rat	18 (13.74%)	11 (15.94%)	11 (22.45%)	88 (76.52%)	31 (11.61%)	0 (0.00%)
Northern treeshrew	6 (4.58%)	16 (23.19%)	10 (20.41%)	3 (2.61%)	0 (0.00%)	0 (0.00%)
Common palm civet	16 (12.21%)	0 (0.00%)	0 (0.00%)	8 (6.96%)	0 (0.00%)	0 (0.00%)
Masked palm civet	1 (0.76%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Pig-tailed macaque	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (0.87%)	0 (0.00%)	0 (0.00%)
Bat	0 (0.00%)	12 (17.39%)	2 (4.08%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
Black-crested bulbul	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (4.55%)
Mountain bulbul	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (4.55%)
Puff-throated bulbul	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	4 (18.18%)
Ashy bulbul	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	16 (72.73%)
Total	131 (100%)	69 (100%)	49 (100%)	115 (100%)	267 (100%)	22 (100%)
χ^2	205.62	8.4058	14.551	301.92	468.69	27.818
df	6	6	5	5	3	3
P-value	<<0.0001	<0.3	<0.02	<<0.0001	<<0.0001	<<0.0001

species can attract frugivores that consume and disperse their seed and consequently add to the potential for tropical forest restoration

Acknowledgments

This research was financially supported by the Thailand Research Fund in the Royal Golden Jubilee (RGJ) Ph.D. Programme and the National Research Council of Thailand (Project: Biodiversity Monitoring on the Climate Changes in Huai Kog Ma Biosphere Reserve and adjacent area of Doi Suthep-Pui Mountain Ecosystems, Chiang Mai Province). In addition, the Kasetsart University Research and Development Institute (KURDI), Bangkok, Thailand provided some research funding for the study. The authors also thank Mr. Niwat Intawin, Ms. Yuwadee Ponpituk, Dr. Warong Suksavate, Ms. Supalak Siri, Mr. Wachirapon Khambucha, Ms. Yuwalak Chanachai, Dr. Sutheera Hermhuk, Mr. Pongsit Srikhunmuang, Mr. Nirawath Narod, Ms. Suttikarn Srisodsuk, Ms. Maratreenung Seehakrai, Ms. Sirinuch Payang, Ms. Pornprapa Anukul, Ms. Jintapa Vijitjan, Ms. Nutthakarn Boonpha and the other students at the Department of Forest Biology, Faculty of Forestry, Kasetsart University, Bangkok, Thailand for their support in the field and statistical analysis.

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