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The Role of Wild Banana (*Musa acuminata* Colla) on Wildlife Diversity in Mixed Deciduous Forest, Kanchanaburi Province, Western Thailand

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ABSTRACT

The roles of wild banana (*Musa acuminata*) on wildlife diversity in mixed deciduous forest were studied at the Mae Klong Watershed Research Station, Kanchanaburi Province, Thailand during 2003-2004. Thirty wild banana individuals were selected and their phenomena were recorded every two weeks. The number of seeds and seed size of ripened fruit samples were counted and measured. The survival of wild banana seedlings was also recorded every month. Wildlife diversity and its relationships to wild banana phenomena were investigated by automatic camera and live traps. The remote automatic camera traps, eight per census, were set up for two nights and three days in places that wild bananas had flowered or fruited every month. Live-traps were also used at the same time with baited banana fruit inside and eight traps were placed near the banana clumps in every census.

The results showed that there was a greater seedling survival of wild bananas from clones than from seeds. The establishment of wild banana was directly from colonized clumps, which showed high efficiency by rapidly occupying the complete disturbed area. Wild bananas flowered and fruited at different times among the culms through the year and facilitated good conditions for both forest regeneration and food resources to wildlife. The results on wildlife diversity showed that 17 species from 16 genera came to utilize the inflorescences, fruits and seeds of wild banana. The roles of wildlife on wild banana could be classified as 1) pollinator by the greater short-nosed fruit bat (*Cynopterus sphinx*), the streaked spiderhunter (*Arachnothera magna*) and the little spiderhunter (*A. longirostra*), 2) seed predator by Pallas's squirrel (*Callosciurus erythraeus*), the gray-bellied squirrel (*C. caniceps*), the Indochinese ground squirrel (*Menetes berdmorei*, *Rattus* spp., *Mus* sp.) and the common treeshrew (*Tupaia glis*), and 3) seed disperser by the Asian palm civet (*Paradoxurus hermaphroditus*). Thus, considering the important roles of wild banana in mixed deciduous forest, it could be classified as a "keystone species", which promotes forest regeneration and provides food resources to wildlife, especially during the dry season.

Key words: seed dispersal, seed predation, frugivores, wild banana, forest regeneration, mixed deciduous forest

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INTRODUCTION

Wild banana (*Musa acuminata*), one of the pioneer plant species, rapidly establishes on disturbed areas where there is a great fluctuation in environmental conditions, especially, high light intensity and large vacant spaces for their regeneration, even though they may not have occupied the site before (Kobayashi *et al*. 1995; Takahashi *et al*. 1995). The questions are firstly, why is wild banana very abundant and secondly, is the succession process quicker following increased disturbance. Two reasons for the rapid establishment on disturbed areas could be firstly, the dependence on long-lived seed dormancy and secondly, their high seed dispersal capacity. However, the relationships between frugivores and seed dispersal have been well documented and not carried out in the natural forests in spite of their importance for the conservation of endangered animals and the forest itself (Corlett, 1996; Turner, 2001; Levey *et al*., 2002). While seed and/or fruit size limits the activities of frugivores that can disperse the seed, large frugivores can handle a wider range of fruit sizes than small frugivores (Noma and Yumoto, 1997; Heindl and Curio, 1999). Wild bananas usually bear fruit several times a year, thus, there is always a supply of food for wildlife that depend on fruit as a major part of their diet, especially during the dry season when other fruit-bearing trees are less productive. In the tropical seasonal forests, wild bananas are considered as a "keystone species", like fig trees, because their characteristics may contribute to an increase in wildlife biodiversity. Thus, the objectives of this study were focused on the role of wild bananas on wildlife diversity and their regeneration, especially by seed dispersal, in mixed deciduous forest.

MATERIALS AND METHODS

Study site

The study was conducted during 2003-2004 in a natural, mixed deciduous forest, (MDF), dominated by undergrowth bamboo at the Mae Klong Watershed Research Station, Thong Pha Phum District, Kanchanaburi Province, in western Thailand. The watershed area is located on a branch of the Kwai Noi River and is approximately 109 km^2 in area, ranging from 100 to 900 m above sea level. The climate is affected by the monsoon; annual rainfall normally exceeds 1,650 mm falling mainly from May to October, and the mean temperature is about 27.5°C with a monthly maximum of 39.1°C in April and a minimum of 14.6°C in December. The parent materials are granite, limestone, sandstone and shale. Phyllite and quartzite are also found is some minor parts of the watershed. The lateritic soils are reddish brown, weathered from parent materials of alluvium and the residuum of sandstone, limestone and quartzite (Suksawang, 1995). The MDF in this area was characterized by an abundant understory of bamboos but an absence of teak (*Tectona grandis*) (Kutintara *et al*., 1995). The dominant tree species were: *Xylia xylocarpa* var. *kerrii*, *Pterocarpus macrocarpus*, *Afzelia xylocarpa*, *Vitex peduncularis* and *Lagerstroemia calyculata*. Four bamboo species (*Gigantochloa albociliata*, *G. hasskarliana*, *Bambusa tulda* and *Cephalostachyum pergracile*) made up the dominant understory (Marod *et al*., 1999, 2005). In 1998 and 2001, two bamboo species (*Gigantochloa albociliata* and *Cephalostrachyum pergracile*) gregariously flowered and died. There were sub-sequence forest fires in 2000, 2002 and 2004. Wild bananas rapidly occupied disturbed sites in the study area, starting from seed germination and expanding by cloning (Kobayashi *et al*., 1995).

Phenological observation of wild banana

Flowering and fruiting

The selected plot area of 200 m × 200 m was located in the MDF. A total of 30 banana clumps, mostly in gaps, (4-6 individuals per clump) were selected and tagged. The clumps had

emerged in 2001, after the bamboo (*Cephalostachyum pergracile*) had died and then experienced the forest fire in 2002. Flowering and fruiting were observed every two weeks. Some sample fruits (n = 70) were harvested to measure the seed size and count the number of fruits.

Seed collecting and seedling investigation

To investigate the quantity of seed dispersal to different sites, the site was searched systematically for feeding roosts around the wild banana clumps in four directions (north, south, east and west) up to a distance of about 150 m from each parent. Statistical test were used to compare seedling survival from the different sources (seed and clone). The new seedlings that emerged from seeds and clones were tagged producing a sample number of 170 and 66 seedlings, respectively. Seedling survival was recorded in every month for a year.

Wildlife diversity

Automatic camera traps were used to investigate the diverse range of wildlife that came to feed on both flowers and fruits of wild bananas. The remote camera traps were placed at sites where wild bananas had flowered or fruited in every census. The automatic camera traps had a far-infrared sensor, motor-drive camera and flash. The blood temperature of animals triggered the camera and each photograph was stamped with the time and date of capture (Miura *et al*., 1997). The cameras were wrapped tightly in a thin, transparent, polypropylene bag to prevent them from getting wet and encased in an unsealed plastic box. Eight camera traps were used for each census and were installed higher than 2 m in each banana culm, close to the flowers and fruits. The camera traps, were set up at sites that wild bananas had flowered or fruited in every month from August 2003 to July 2004. Each census period consisted of three days and two nights, commencing at 9.00 am and continuing until the end of the study period. The frugivores from camera trap photos were identified according to Lekagul and McNeely (1977). The amount of trapping effort required (in camera-days) was calculated for each camera from the time that the camera was mounted until it was retrieved. The total trapping effort in a census was defined as the sum of the camera-days of the eight camera traps. The dominant species were defined by the relative frequency (RF) of animals according to Khobkhet (1999), using Equation 1:

$$\text{RF of Species A} = \frac{\text{Number of pictures (traps) with species A} \times 100}{\text{Total number of pictures for all species (traps)}} \quad (1)$$

In addition, live traps (15 cm × 15 cm × 30 cm) were also set up to support the automatic camera trap data, which were established at the same time, with a total of 36 days of observation in a year. For every census, eight live-traps were used in each wild banana clump, with a north-south, east-west distribution. The live-traps were baited with banana fruit and captured wildlife were identified and measured. Pollinators, especially the nocturnal species, such as bats, were captured using nets around the banana culms.

RESULTS

Wild banana phenology

After gregarious bamboo flowering, followed by the forest fire, wild banana (*Musa acuminata*) rapidly and almost completely occupied the disturbed area (65% occupancy, Figure 1), especially in the open areas. The average count was 4.47 ± 1.2 culms per clump; the flowering and fruiting periods were different from other plants. Their inflorescence structures and flowering phenomena usually prevent pollen transfer within the same inflorescence. Flowering and fruiting occurred at different times through the year, with plants dying soon after these phenomena. The period of development from flower to fruit took about four months and ripening occurred from the base to the apex of the inflorescence. The average number of fruits in each

inflorescence and fruit size (± S.D.) were 161.76±60.62 individuals per inflorescence and 2.4±0.32 cm × 9±1.2 cm, respectively. The wild banana fruits had many seeds inside, with 72.5±2.4 seeds per fruit and a seed size of 17.65±0.35 mm × 26.30±0.53 mm.

The survival rate for seedlings that emerged direct from seeds (n = 170) and clones (n = 66) through the year was highly significantly different (Z= -3.64, $p < 0.001$), with the former having a lower annual survival rate than the latter, 30.90±28.38 and 87.32±9.45 % y^{-1}, respectively. These data indicated that the establishment of wild banana directly from colonized clumps was a highly efficient means of rapidly occupying the whole area. In addition, this may have been aided by the susceptibility of wild banana seedlings to fire as they were mostly burnt by forest fire during the dry season.

The diversity of wildlife

The wildlife detected from 669 photographs taken by the automatic camera traps consisted of 15 species from 14 genera. The highest relative frequency was for the gray-bellied squirrel (*Callosciurus caniceps*) (49.03%) followed by Pallas's squirrel (*C. erythraeus*) (14.65%), rats (*Rattus* spp.) (10.91%), the greater short-nosed fruit bat (*Cynopterus sphinx*) (10.91%), the Asian palm civet (*Paradoxurus hermaphroditus*) (6.13%), the common treeshrew (*Tupaia glis*) (5.68%), the Indochinese ground squirrel (*Menetes berdmorei*) (0.75%), the blue-winged pitta (*Pitta moluccensis*) (0.60%), the Asian barred owlet (*Glaucidium cuculoides*) (0.30%), the greater yellownape (*Picus flavinucha*) (0.30%), the streaked spiderhunter (*Arachnothera magna*) (0.15%), the white-rumped shama (*Copsychus malabaricus*) (0.15%), mice (*Mus* sp.)

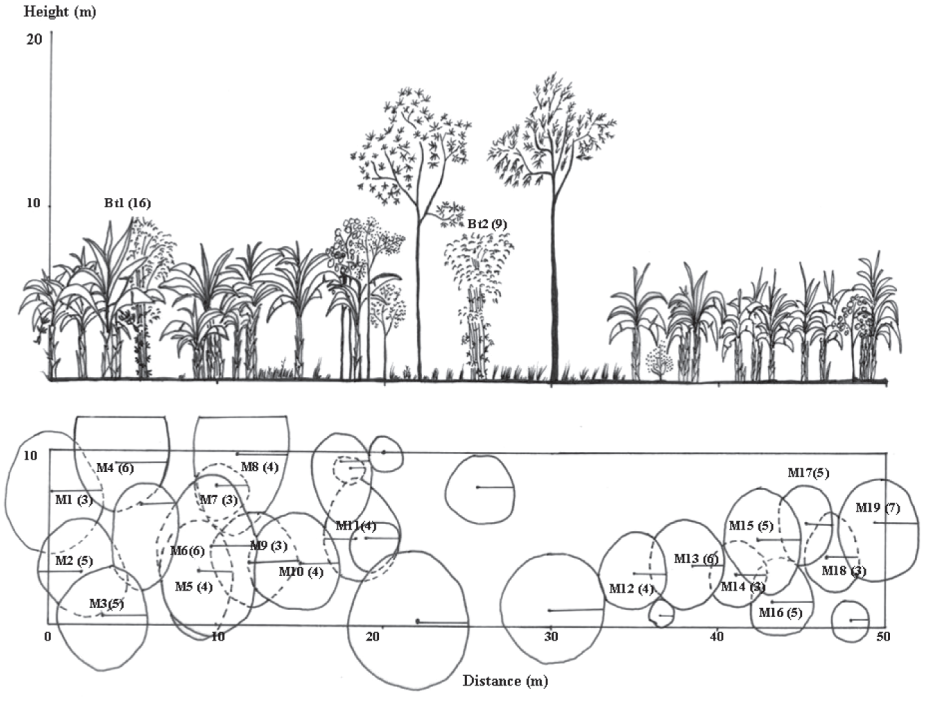

Figure 1 Profile and crown cover diagram of a wild banana community in seasonal tropical forest after mass flowering of bamboos. Ma = (*Musa acuminata*), Bt = (*Bambusa tulda*), Co = (*Croton oblongifolius*), Oi = (*Oroxylum indicum*), Fa = (*Fernando nadenophylla*), Vc = (*Vitex canescens*), Sn = (*Stereospermum neuranthum*, and Aa = (*Anogeissus acuminate* var. *lanceolata*). Ma1(4) = mean of clump number 1 of *Musa acuminata* with 4 culms.

(0.15%), the velvet-fronted nuthatch (*Sitta frontalis*) (0.15%) and the oriental bay owl (*Phodilus badius*) (0.15%), respectively. All species came to feed on wild banana inflorescence in different periods according to the flowering and fruiting (raw and ripe) stages. However, the most useful food source for wildlife was the ripe fruits, which were detected in 81.16 % of photos. The abundant wildlife species, (the gray-bellied squirrel, Pallas's squirrel and the Asian palm civet), visited wild banana clumps during both flowering and fruiting periods. The detected wildlife could be clearly divided into two groups according to feeding time: 1) diurnal species (gray-bellied squirrel, Pallas's squirrel, Indochinese ground squirrel and common treeshrew) and 2) nocturnal species (rats (*Rattus* spp.), the Asian palm civet and the greater short-nosed fruit bat) (Figure 2).

The results from 680 live-trap captures showed that four genera and four species were captured in 87 traps. *Rattus* spp. showed the highest abundance (54 %), followed by mice (*Mus* sp.), the Indochinese ground squirrel, and the common treeshrew with 18.39, 18.39 and 9.20%, respectively. The total captured species favored males over females, with an average sex ratio of 1:0.4, respectively. This may have resulted from the behavior of males who are much more aggressive and have a larger home range than females. Most captures were during the dry season, with about 20% each month, probably due to a lower abundance of fruit-bearing trees during this time, as trapped animals were near wild bananas. It may also have been influenced by the different flowering and fruiting periods among the culms and clumps, which meant that fruit could be produced all year round. Consequently, bananas constitute the main food resources for wildlife in the MDF, especially during the dry season when there are less fruit-bearing trees.

Interaction between wild banana and wildlife

The interaction between flowering and fruiting of the wild banana and wildlife showed that 17 species from 16 genera of wildlife (Table 1) visited wild bananas and utilized flowers and

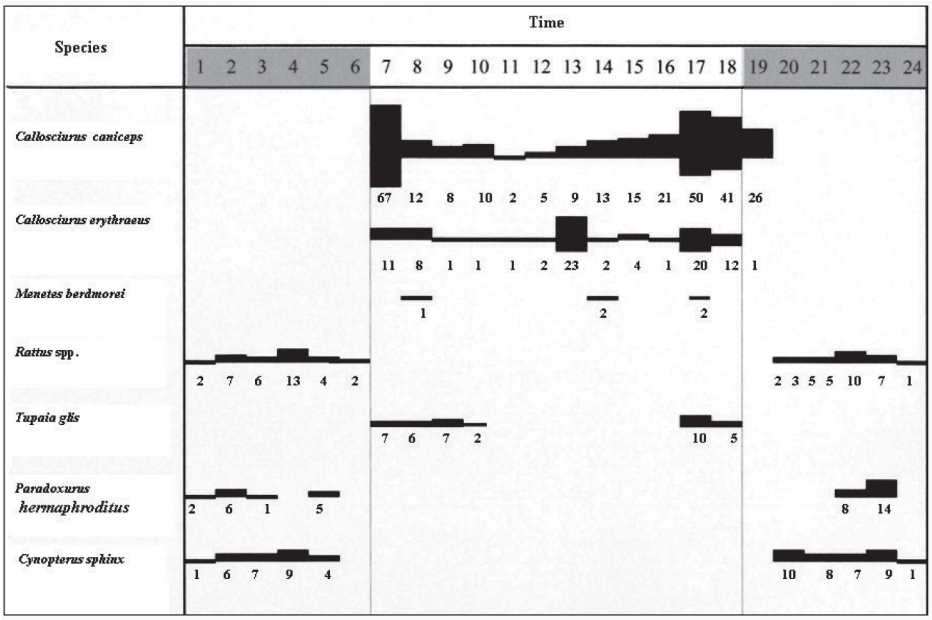

Figure 2 Feeding period of some dominant wildlife on wild banana inflorescence. The black bars and numbers indicated the frequency of recorded photographs by camera traps and the gray area in the timescale indicates nighttime.

fruits. The wild bananas produced a large amount of fruit (161.76 ± 60.62 individual per inflorescence) containing many seeds (72.5 ± 2.4 seeds per fruit). This may have been an adaptation to seed competitors and the seed dispersal agents. The results showed that only the Asian palm civet could be classified as a seed disperser, through defecation on the forest floor away from the mother culms, as was similarly reported by Kitamura *et al*. (2002), with less than 20% of seeds damaged from their chewing. The size of the Asian palm civet is about 2-5 kg, which is larger than other frugivores found at the study sites. In contrast, six other species (Pallas's squirrel, the gray-bellied squirrel, the Indochinese ground squirrel, rats (*Rattus* spp.), mice (*Mus* sp.) and the common treeshrew) were seed competitors or predators that destroyed over 80% of seeds by chewing.

The pollinators were also very important for wild banana regeneration as the banana's inflorescence structure usually prevents pollen transfer within the same inflorescence. The results from camera traps during flowering period produced 75 photos that detected three genera and four species (the greater short-nosed fruit bat, the streaked spiderhunter, the gray-bellied squirrel and Pallas's Squirrel). The first two species visited flowers very frequently, about 56.0 and 18.7%, respectively, utilizing the nectar and pollen from the flowers. Feeders can be divided into nocturnal and diurnal species, suggesting that these species may influence wild banana pollination, though the last two species (the gray-bellied squirrel, and Pallas's squirrel), might visit the site for other purposes that were not detected from the camera trap photos.

DISCUSSION

The importance of mammals as dispersers has been recognized and documented by many authors in most parts of the world. Ripe fruit of wild bananas is very attractive to frugivores and fruits or seeds can be dispersed away from the parent clumps. Wild bananas usually produce large amount of flowers and seeds, which are easily dispersed. This characteristic is similar to other pioneer species (Swain and Whitmore, 1988). However, most pioneer species had a wide range variation in reproductive traits (Grubb, 1996; Dalling *et al*., 1997) that may influence the ability of species to colonize spatially unpredicted forest gap areas. The frugivores, especially mammalian herbivores, influence the function of many ecosystems due to their impact on primary production, decomposition of organic matter and redistribution of nutrients (Batzli, 1978). The starchy fruit in wild bananas apparently offered a good food source to frugivores, in particular small mammals, such as the Asian palm civet, the gray-bellied squirrel, the common treeshrew and rats, so that via these agents, seeds of wild banana could be distributed away from the parents. The seed dispersers, for example, the common palm civet, usually disperse the seed via defecation (Kitamura *et al.,* 2002). This species (head and body (HB) length 43-71 cm and weight (W) 3-5 kg) is usually larger than the squirrels abundant in the areas (HB 21-26 cm and W 0.2-0.3 kg). The Asian palm civet took fruit from the inflorescence of wild bananas much further away from parent clumps than other small rodents, such as squirrels or rats, indicating that the large frugivores can handle a wider range of fruit sizes than small frugivores (Wheelwright, 1985; Noma and Yumoto, 1997). However, the frugivores were not only dispersers of seeds, but also could be destroyers too. The results showed that only the Asian palm civet could be classified as a seed disperser, while the other species of small mammals, such as *Callosciurus*, *Tupaia*, and *Rattus*, were seed competitors, as reported elsewhere (Hoshizaki, 1999; Wolff, 1999). Wild banana regeneration is influenced by both seed dispersers and competitors. In addition, their adapted traits will eventually maintain species coexistence in the mixed deciduous forest dynamics.

Table 1 The roles of some dominant frugivores on wild banana regeneration in mixed deciduous forest, western Thailand.

No.	Common name	Scientific name	Family	Feeding period[1]	Feeding location [2]	Utilize parts[3]	Roles on wild banana[4]
1	Gray-bellied Squirrel	*Callosciurus caniceps* (Grey) 1842	Sciuridae	DN	A	Fr, Fl	Pr
2	Pallas's Squirrel	*Callosciurus erythraeus* (Pallas) 1779	Sciuridae	DN	A	Fr, Fl	Pr
3	Indochinese Ground Squirrel	*Menetes berdmorei* (Blyth) 1849	Sciuridae	D	T	Fr	Pr
4	-	*Mus* sp.	Muridae	N	T	Fr	Pr
5	-	*Rattus* spp.	Muridae	DN	AT	Fr	Pr
6	Common Treeshrew	*Tupaia glis* (Diard) 1820	Tupaidae	D	AT	Fr	Pr
7	Asian Palm Civet	*Paradoxurus hermaphroditus* (Pallas) 1777	Viverridae	N	A	Fr	D
8	Greater Short-nosed Fruit Bat	*Cynopterus sphinx* (Vahl) 1797	Pteropodidae	N	A	Fl, Fr	Po
9	White-rumped Shama	*Copsychus malabaricus* (Scopoli) 1788	Muscicapidae	D	A	UN	ND
10	Greater Yellownape	*Picus flavinucha* (Gould) 1834	Picidae	D	A	UN	ND
11	Streaked Spiderhunter	*Arachnothera magna* (Hodgson) 1837	Nectariniidae	D	A	Fl	Po
12	Little Spiderhunter	*Arachnothera longirostra* (Latham) 1790	Nectariniidae	D	A	Fl	Po
13	Oriental Bay Owl	*Phodilus badius* (Horsfield) 1821	Tytonidae	N	A	UN	ND
14	Asian Barred Owlet	*Glaucidium cuculoides* (Vigors) 1831	Strigidae	N	A	UN	ND
15	Blue-winged Pitta	*Pitta moluccensis* (Mueller) 1776	Pittidae	D	T	UN	ND
16	-	*Ficedula* sp.	Muscicapidae	D	A	UN	ND
17	Velvet-fronted Nuthatch	*Sitta frontalis* (Horsfield) 1821	Sittidae	D	A	UN	ND

Remarks: [1] Feeding period; 6.00 am - 18.00 pm = Diurnal, D; 18.00 pm - 6.00 am = Nocturnal, N and DN = Diurnal-Nocturnal

[2] Feeding location; A = Arboreal, T = Terrestrial, and AT = Arboreal-Terrestrial

[3] Utilize parts; Fr = Fruit, Fl = Flower, and UN = Unknown

[4] Roles on wild banana; D = Dispersed, ND = Not Dispersed, Pr = Predator, Po= Pollinator, and UN = Unknown

Keystone species of both plants and wild animals are widely accepted as providing supporting roles in biological diversity. A keystone species is a species that provides an essential contribution to the diversity of life and whose extinction would consequently lead to the extinction of other forms of life (Bruce *et al*., 1994; Power *et al*., 1996). Keystone species help to support ecosystems (the entire community of life), contributing to ecosystem functions as producers, consumers, or decomposers, etc (Paine, 1969; Holt, 1984; Mills *et al*., 1993). *Musa* (Musaceae) have been identified as prime examples of flowers adapted morphologically for bird or bat pollination (Liu *et al*., 2002) with these animals using them as a food source. In addition, they rapidly established in the disturbed areas and provided good facilities to alter the direction of succession (Zhang *et al*., 2000). Thus, considering the its roles in both environmental facilitation and food resource support, wild banana could be classified as a "keystone species" in the mixed deciduous forest.

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LITERATURE CITED

Batzli. 1978. Influence of supplemental feeding on a vole population. **J. Mammal.** 59: 809–819.

Bruce A. M., L.B. Eric, A.B. Carol, A.N. Sergio and B.Y. Sylvia. 1994. The Keystone Species Concept: Variation in Interaction Strength in a Rocky Intertidal Habitat. **Ecol. Mono.** 64 (3): 249–286.

Corlett, R.T. 1996. Characteristics of vertebrate dispersed fruits in Hong Kong. **J. Trop. Ecol.** 12: 819-833.

Dalling, J.W., M.D. Swaine and N.C. Garwood. 1997. Soil seed bank community dynamics in seasonally moist lowland tropical forest, Panama. **J. Trop. Ecol.** 13: 659-680.

Grubb P.J. 1996. Rain forest dynamics: the need for new paradigms, pp 215–233. *In* D.S. Edwards, W.E. Booth and S.C. Choy (eds.). **Tropical Rainforest Research Current Issues.** Kluwer , Dordrecht,

Holt, R.D. 1984. Spatial heterogeneity, indirect interactions, and the coexistence of prey species. **The American Naturalist** 124: 377–406.

Heindl, M. and E. Curio. 1999. Observations of frugivorous birds at fruit-bearing plants in the north Negros Forest Reserve, Philippines. **Ecotropica** 5: 167-181.

Hoshizaki, K. 1999. **Regeneration Dynamics of a Sub-dominant Tree Aesculus Turbinate in a Beech-dominated Forest: Interactions between Large-seeded Tree Guild and Seed/Seeding Consumer Guild**. Doctoral thesis. Center for Ecological Research, Kyoto University, Japan.

Khobkhet, A. 1999. Techniques in wildlife studies, pp. 207-230. *In* W. Issara (ed.). **Biological Diversity Reports; Methodology of Diversity Study**. Kasetsart University, Bangkok.

Kitamura, S., T. Yomoto, P. Poonswad, P. Chuailud, K. Plongmai, T. Maruhashi and N. Noma. 2002. Interactions between fleshy fruits and frugivores in a tropical seasonal forest in Thailand. **Oecol.** 133: 559-572.

Kobayashi, S., Y. Chanchai and P. Pornphitak. 1995. Population dynamics of wild banana (*Musa acuminata*) related with the succession of the logged-over forest, pp. 165-169. *In* **The**

International Workshop on the Change of Tropical Forest Ecology by EL NiÒo and Others. National Research Council, Thailand.

Kutintara, U., D. Marod, M. Takahashi and T. Nakashizuka. 1995. Growth and dynamics of bamboos in a tropical seasonal forest, pp. 165-169. *In* **The International Workshop on the Change of Tropical Forest Ecology by EL NiÒo and Others.** National Research Council, Thailand.

Lekagul, B. and J.A. McNeely. 1977. **Mammals of Thailand**. Kurusapha Ladprao Press, Bangkok.

Levey, D.J., W.R. Silva and M. Galetti. 2002. **Seed Dispersal and Frugivory: Ecology, Evolution and Conservation**. CABI Publishing, New York.

Liu, A.Z, D.Z Liz and H. Wong. 2002. Ornithophilous and Chiropterophilous Pollination in *Musa itinerans* (Musaceae), a Pioneer Species in Tropical Rain Forests of Yunnan, Southwestern China. **Biotropica** 34(2): 254-260

Marod, D., U. Kutintara, C. Yarwudhi, H. Tanaka and T. Nakashisuka. 1999. Structural dynamics of a natural mixed deciduous forest in western Thailand. **J. Veg. Sci.** 10: 777-786.

Marod, D., V. Neumrat, S.Panuthai, T. Hiroshi and P. Sahunalu. 2005. The forest regeneration after gregarious flowering of bamboo (*Cephalostachyum pergracile*) at Mae Klong Watershed Research Station, Kanchanaburi. **Kasetsart J. (Nat. Sci.)** 39: 588-593.

Mills, S., M.E. Soule and D.F. Doak. 1993. The keystone-species concept in ecology and conservation. **BioSci.** 43: 219–226.

Miura, S., M. Yasuda and L.C. Ratnum. 1997. Who steals the fruits? Monitoring frugivory of mammals in a tropical rain forest. **Malayan Nat. J.** 50: 183-193.

Noma, N. and T. Yumoto. 1997. Fruiting phenology of animal-dispersed plants in response to winter migration of frugivores is a warm temperate forest on Yakushima Island, Japan. **Ecol. Res.** 12: 119-129.

Paine, R.T. 1969. A note on trophic complexity and community stability. **The American Naturalist** 103: 91–93.

Power, M.E., D. Tilman, J.A. Estes, B.A. Menge, W.J. Bond, L.S. Mills, G. Daily, J.C. Castilla, J. Lubchenco and R.T. Paine. 1996. Challenges in the quest for keystones. **Biosci.** 46: 609–620.

Suksawang, S. 1995. Site overview: Thong Pha Phum study site, pp. 33-37. *In* **The International Workshop on the Change of Tropical Forest Ecology by EL NiÒo and Others**. National Research Council, Thailand.

Takahashi, M., U. Kutintara, W. Eaidthong and S. Kobayashi. 1995. Changes of the vegetation pattern in different successional stages. pp. 116-124. *In* **International Workshop on Changes of Tropical Forest Ecosystems**. National Research Council, Bangkok.

Turner, I.M. 2001. **The Ecology of Trees in the Tropical Rain Forest.** Cambridge University Press, New York. 298 p.

Wheelwright, N.T. 1985. Fruit size, gape width, and the diets of fruit-eating birds. **Ecol.** 66: 808-818.

Wolff, J. O. 1996. Coexistence of white-footed mice and deer mice may be mediated by fluctuating environmental condition. **Oecol.** 108: 529 533.

Zhang, M., J.W. Tangj, J.P Shi and K.J. Bai. 2000. Niche dynamics of dominant populations of *Musa itineranr* Cheesmen pioneer community in Xishuangbanna, SW China. **J. Plant Res. Environ.** 9: 22-26.