

Taxonomic Studies and Traditional Uses of Zingiberaceae in Khao Luang National Park, Nakhon Si Thammarat Province, Thailand

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Abstract

Taxonomic studies and traditional uses of Zingiberaceae were conducted in Khao Luang National Park from March 2011 to March 2012, in order to study species diversity, ecology, distribution, and uses. Plant samples were collected from 6 waterfalls in the southern part of the park. Thirty-four species in 10 genera, 3 tribes of Zingiberaceae were collected. A key to species for each genus is provided. Four taxa could not yet be identified. Ka Rome waterfall has the highest number of Zingiberaceae species (23 species in 10 genera, $H' = 3.091$, $D' = 0.948$) because this area may be less disturbed. Some areas of the park were degraded and changed to plantations, such as Wang Mai Pak waterfall, which has the lowest number of species (13 species in 7 genera, $H' = 2.432$, $D' = 0.904$). Information on traditional uses of the collected plants was gathered by interviewing villagers and folks who live nearby the areas. Zingiberaceae plants are found to be important natural resources for villagers and mostly used as medicines, foods, drinks, and ornaments.

Keywords: Zingiberaceae, taxonomic studies, traditional uses, Khao Luang National Park

Introduction

Zingiberaceae is a monocot plant, and is the largest of 8 families in the order Zingiberales. There are about 53 genera and over 1,200 species in the family [1]. They are mostly distributed over tropical and subtropical areas, but the center of distribution is in Southeast Asia. Zingiberaceae plants were previously classified based on only morphological features. This classification had been accepted widely [2-6]. Kress *et al.* [1] proposed a new classification of Zingiberaceae, based on morphological characters and molecular phylogeny, composing of 4 subfamilies and 6 tribes: Siphonochiloideae (Siphonochileae), Tamijioideae (Tamijieae), Alpinoideae (Alpinieae, Riedelieae), and Zingiberoideae (Zingibereae, Globbeae).

Thailand is one of the countries that exhibit a rich diversity of Zingiberaceae plants. Twenty-six genera and more than 300 species were reported by Larsen and Larsen [7]. Zingiberaceae plants mostly grow in damp and humid shady places, and are also found from the lowlands to the highest elevations in secondary and primary forests. There is a high number of Zingiberaceae species in Peninsular Thailand, because the climate and landscape support the plant's growth. Fifteen genera that are found are *Alpinia*, *Amomum*, *Boesenbergia*, *Curcuma*, *Camptandra*, *Caulokaempferia*, *Etilingera*, *Elettariopsis*, *Globba*, *Geostachys*, *Hedychium*, *Kaempferia*, *Plagiostachys*, *Scaphochlamys*, and *Zingiber* [8-14]. The highest mountain peak of Peninsular Thailand is in Khao Luang National Park (1,835 m above sea level). Khao Luang National Park is located in the north-west of Nakhon Si Thammarat province, Peninsular Thailand, covering an area of about 1.4×10^5 acres. Most of the Khao Luang area, about 119.6 acres, has seen

disturbed through trespassing and by changing the area into rubber plantation or mixed crop plantation by villagers who live near the park. The staff of Khao Luang National Park have been demolishing these plantations and rehabilitating these areas [15]. Two endemic Zingiberaceae species: *Boesenbergia basispicata*, K. Larsen ex Sirirugsa [8] and *Zingiber newmanii*, Theilade & Mood [16], were reported in Khao Luang National Park. Seven Zingiberaceae species at one station of Khao Luang National Park, Krung Ching waterfall, were reported [12]. At present, many wild Zingiberaceae species are becoming rare and are threatened by human activities. Forty-five species of Zingiberaceae are rare plants of Peninsular Thailand [17]. To date, taxonomic studies of Zingiberaceae in Khao Luang National Park have not yet been fully completed. The aim of this study is to enumerate species diversity, and to study ecology, distribution, and traditional uses of Zingiberaceae plants in the park. Taxonomic and ecological data of the plants are important information for efficient biological resource management for the national park.

Materials and methods

Area of study

This study focused on the southern part of Khao Luang National Park, Nakhon Si Thammarat province, Thailand, partly because the northern part of the park was covered in our previous study [12]. There are 6 accessible waterfalls in the southern part of the park, and, thus, the following were selected for this study; Suan Ai waterfall¹, Suan Khan waterfall², Sri Nun waterfall³, Tha Pae waterfall⁴, Ka Rome waterfall⁵, and Wang Mai Pak waterfall⁶. The total area covers about 280 km² (**Figure 1**). Four types of habitat were observed in the study sites. They were secondary forest, bamboo forest, rubber plantation and mixed crop plantation.

Field survey

Plant collection permission was granted by Royal Forest Department (กรมป่าไม้/ประเทศไทย). The plants were collected from both sides of waterfall stream and walking trails, every month within one year. Once the ginger population was found, wherever possible, the number of individuals was counted. Otherwise, the whole area of the population was calculated and classified by its size into either: big clumps (5×5 m) = 30 individuals, middle clumps (2×2 m) = 10 individuals, and small clumps (0.2×0.2 m) = 4 individuals, in order to gain the individual numbers. All plant samples were kept in plastic bags and used as voucher specimens and morphology studies. The phenological period was flowering and fruiting time, which was recorded every month in 1 year. Elevation was recorded by using GPS 76Cx.

Information on Zingiberaceae use was collected by interviewing villagers and folks who lived nearby the study sites. The data consisted of part use, usefulness, and medicinal preparation form. Villagers and folks were older than 45 years, and at least 3 persons were chosen in each study site. The number of villagers and folks interviewed from the study sites varied from 4 to 12. In total, there were 36 informers, aged between 45 - 76 years old. The average male informer to female informer ratio was 2:1.

Laboratory work

Plant morphology was studied by using a stereo microscope. Morphological characters of the plant samples were recorded and used for species identification. All specimens were kept in the Walailak University Botanical Garden and Thailand Department of Forestry Herbaria (BKF).

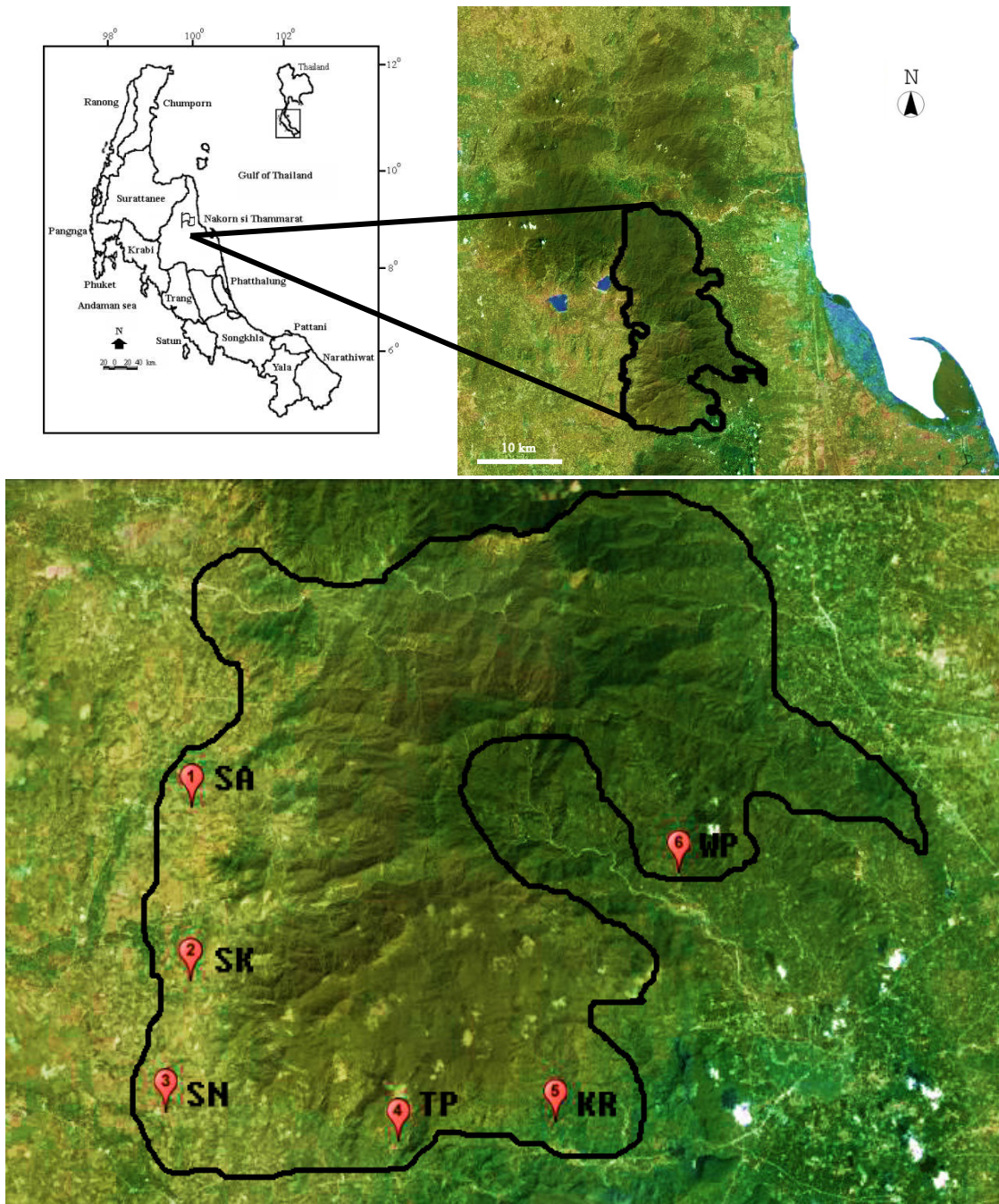


Figure 1 Study sites. SA = Suan Ai waterfall, SK = Suan Khan waterfall, SN = Sri Nun waterfall, TP = Tha Pae waterfall, KR = Ka Rome waterfall, WP = Wang Mai Pak waterfall.

Plant diversity index

Species richness was calculated as the total number of individual and species in each study site or habitat. There are 2 diversity indexes [18].

1) Shannon-Wiener Diversity Index (H') is calculated using the following equation;

$$H' = -\sum_{i=1}^S Pi(\ln Pi) \tag{1}$$

where Pi is the proportion of individuals in a species, and S is number of species.

2) Simpson's Diversity Index (D') is calculated using the following equation;

$$D = \sum_{i=1}^S n(n-1)/N(N-1) \tag{2}$$

$$D' = 1 - D \tag{3}$$

where S is the proportion of species, n is the percentage cover of individuals in a species, and N is the total number of species in each study site or habitat.

Results and discussion

Species diversity

Thirty-four species were collected from 6 waterfalls of Khao Luang National Park and classified in 10 genera, 3 tribes (**Table 1**). Tribe Alpinae, which had the highest diversity of Zingiberaceae species, composed 5 genera and 15 species. Tribe Zingibereae, which had the second highest diversity of Zingiberaceae species, composed 5 genera and 13 species. Tribe Globeae, which had the least diversity of Zingiberaceae species, composed one genera and 4 species. The illustrations of 34 species, including 2 varieties of Zingiberaceae plants, are provided (**Figure 2**).

Table 1 Distribution, phenology and IUCN assesment of Zingiberaceae plants in southern part of Khao Luang National Park.

No	Species name	Study sites						Habitat types				Phenology		IUCN assesment (this study)	
		SA	SK	SN	TP	KR	WP	SF	BF	RP	MP	Flowering time	Fruiting time		
1	<i>Alpinia mutica</i> Roxb.					X				X			Apr-Jun	Apr-Jun	DD
2	<i>Alpinia siamensis</i> K.Schum	X	X	X	X	X	X						May-Aug	Sep-Nov	LC
3	<i>Alpinia zerumbet</i> (Pers.) Burt & R.M.Sm.			X							X		Aug-Sep	Mar-May	DD
4	<i>Amomum aculeatum</i> Roxb.	X						X					Apr-Jun	May-Oct	DD
5	<i>Amomum rivale</i> Ridl.				X	X		X					Jul-Sep	Aug-Nov	DD
6	<i>Amomum testaceum</i> Ridl.					X		X					Feb-Jul	Mar-Jul	DD
7	<i>Amomum uliginosum</i> J.König	X			X	X	X	X					May-Oct	May-Oct	LC
8	<i>Amomum villosum</i> var. <i>xanthioides</i> (Wall. ex Bak.) T.L.Wu & S.J.Chen		X					X		X	X		May-Sep	Jun-Oct	DD
9	<i>Amomum villosum</i> var. <i>villosum</i>		X						X				Jul-Oct	Jul-Oct	DD
10	<i>Boesenbergia basispicata</i> K.Larsen ex Siriruga					X		X					Jul-Oct	Jul-Oct	DD
11	<i>Boesenbergia curtisii</i> (Bak.) Schltr.		X							X			Jul-Oct	Jul-Oct	DD

No	Species name	Study sites					Habitat types				Phenology		IUCN assessment (this study)	
		SA	SK	SN	TP	KR	WP	SF	BF	RP	MP	Flowering time		Fruiting time
12	<i>Boesenbergia longipes</i> (King & Prain ex Ridl.) Schltr.				X					X		Jul-Dec	Jul-Dec	DD
13	<i>Boesenbergia plicata</i> (Ridl.) Holtt.	X	X			X		X				Sep-Nov	Sep-Nov	DD
14	<i>Boesenbergia rotunda</i> (L.) Mansf.	X	X	X	X	X	X					Jul-Sep	Jul-Sep	DD (LC)
15	<i>Curcuma aurantiaca</i> Zijp.	X	X							X		Nov-Dec	-	DD
16	<i>Curcuma longa</i> L.	X	X	X	X	X	X					-	-	LC
17	<i>Curcuma zedoaria</i> (Christm.) Rosc.	X	X	X	X	X	X					Apr-Jun	Apr-Jun	DD
18	<i>Elettariopsis curtisii</i> Bak.	X	X	X	X	X		X		X		May-Jun	-	DD (LC)
19	<i>Etilingera elatior</i> (Jack) R.M.Sm.	X	X	X	X	X	X					All year	All year	DD (LC)
20	<i>Etilingera fulgens</i> (Ridl.) C.K.Lim.				X			X				Apr-Jun	Jun-Aug	DD
21	<i>Etilingera littoralis</i> (J.König) Giseke	X	X	X	X	X	X	X				Sep-Nov	Oct-Nov	LC
22	<i>Etilingera subterranea</i> (Holt.) R.M.Sm.		X		X		X	X		X		Oct-Dec	-	DD
23	<i>Etilingera</i> aff. <i>littoralis</i> (Form 1)					X		X				Sep-Nov	-	DD
24	<i>Etilingera</i> aff. <i>littoralis</i> (Form 2)						X	X		X		Sep-Nov	-	DD
25	<i>Globba pendula</i> Roxb.	X	X	X	X	X		X				Jun-Dec	Jun-Dec	LC
26	<i>Globba schomburgkii</i> Hook.f.			X						X		Jun-Dec	Jun-Dec	DD
27	<i>Globba</i> sp.1					X		X				Jun-Dec	Jun-Dec	DD
28	<i>Globba</i> sp.2	X	X	X	X	X				X		All year	All year	DD
29	<i>Hedychium coronarium</i> J.König	X	X	X	X	X	X					All year	All year	LC
30	<i>Kaempferia pulchra</i> Ridl.					X		X				Apr-Dec	-	LC
31	<i>Zingiber gramineum</i> Noronha ex Blume			X						X		Aug-Sep	-	DD
32	<i>Zingiber newmanii</i> Theilade & Mood	X	X	X	X	X	X	X	X	X		Apr-Oct	Jun-Oct	DD (LC)
33	<i>Zingiber officinale</i> Rosc.	X	X	X	X	X	X					All year	All year	LC
34	<i>Zingiber spectabile</i> Griff.	X	X			X		X				Feb-Apr	Feb-Apr	DD
35	<i>Zingiber zerumbet</i> (L.) Sm.	X	X	X	X	X	X	X	X	X		Aug-Sep	Sep-Oct	LC

Study sites: SA = Suan Ai waterfall, SK = Suan Khan waterfall, SN = Sri Nun waterfall, TP = Tha Pae waterfall, KR = Ka Rome waterfall, WP = Wang Mai Pak waterfall

Habitat types: SF = Secondary forest, BF = Bamboo forest, RP = Rubber plantation, MP = Mixed crop plantation

IUCN assessment: LC = Least concern, DD = Data deficient

Month: Jan = January, Feb = February, Mar = March, Apr = April, May = May, Jun = June, Jul = July, Aug = August, Sep = September, Oct = October, Nov = November, Dec = December

Shannon Wiener's Diversity Index indicated a general tendency that Ka Rome waterfall > Suan Khan waterfall > Suan Ai waterfall > Tha Pae waterfall > Sri Nun waterfall > Wang Mai Pak waterfall (**Table 2**). Simpson's Diversity Index showed no significant difference in the values among each waterfall, but indicated the highest diversity in Ka Rome waterfall ($D' = 0.948$), and the lowest diversity in Wang Mai Pak waterfall ($D' = 0.904$). Ka Rome waterfall has the highest number of Zingiberaceae species (23 species), due to the forest being rather healthy compared to the other waterfalls in this study. Most of the Khao Luang area have been changed into rubber plantation or mixed crop plantation by villagers, especially Wang Mai Pak waterfall. Wang Mai Pak waterfall is located in Khiriwong Village, Tha Dee subdistrict, Lansaka district, Nakhon Si Thammarat province, Thailand. Villagers who live in Khiriwong Village have made rubber and mixed crop plantation for many generations. Therefore, only 13 species were found in Wang Mai Pak waterfall.

The southern part of Khao Luang National Park is a rainforest area, and covers diverse habitats. Four types of habitat can be classified. They are secondary forest, bamboo forest, rubber plantation, and mixed crop plantation. Most ginger plants in this study grow well in secondary forest ($H' = 2.555$, $D' = 0.896$). Only one species, *Amomum villosum* var. *villosum* grows in bamboo forest ($H' = 0.401$, $D' = 0.214$), as shown in **Table 3**.

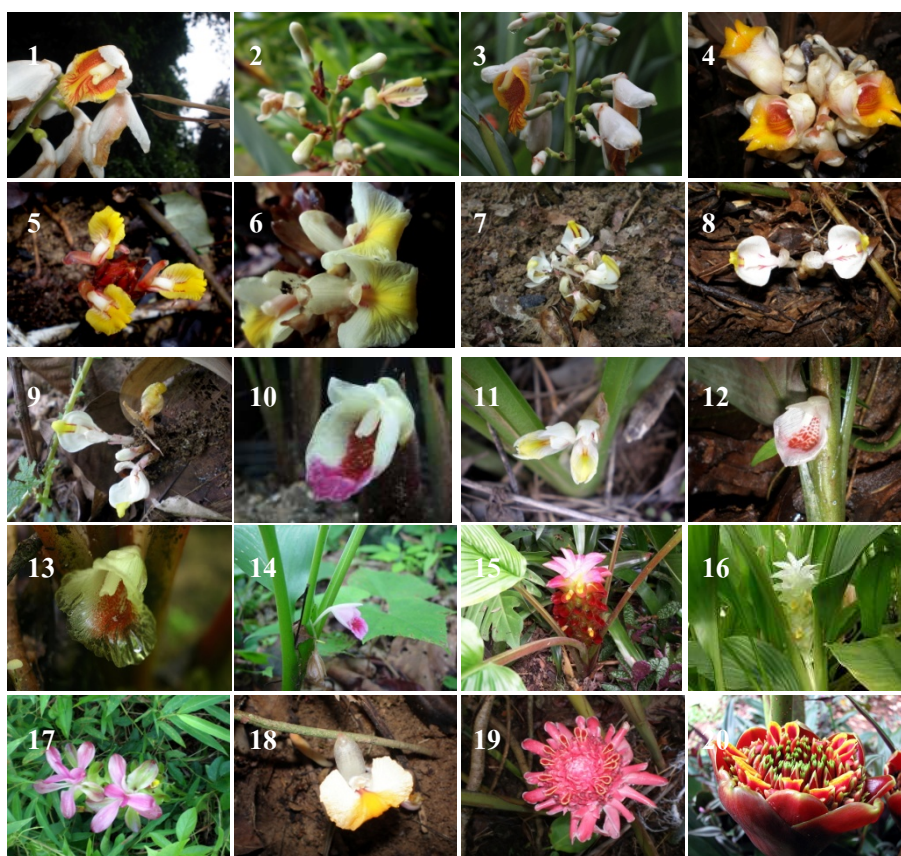




Figure 2 Thirty-five taxa of Zingiberaceae plants. *Alpinia mutica* (1), *Alpinia siamensis* (2), *Alpinia zerumbet* (3), *Amomum aculeatum* (4), *Amomum rivale* (5), *Amomum testaceum* (6), *Amomum uliginosum* (7), *Amomum villosum* var. *xanthioides* (8), *Amomum villosum* var. *villosum* (9), *Boesenbergia basispicata* (10), *Boesenbergia curtisii* (11), *Boesenbergia longipes* (12), *Boesenbergia plicata* (13), *Boesenbergia rotunda* (14), *Curcuma aurantiaca* (15), *Curcuma longa* (16), *Curcuma zedoaria* (17), *Elettariopsis curtisii* (18), *Etilingera elatior* (19), *Etilingera fulgens* (20), *Etilingera littoralis* (21), *Etilingera subterranea* (22), *Etilingera* aff. *littoralis* (Form 1) (23), *Etilingera* aff. *littoralis* (Form 2) (24), *Globba pendula* (25), *Globba schomburgkii* (26), *Globba* sp.1 (27), *Globba* sp.2 (28), *Hedychium coronarium* (29), *Kaempferia pulchra* (30), *Zingiber gramineum* (31), *Zingiber newmanii* (32), *Zingiber officinale* (33), *Zingiber spectabile* (34), *Zingiber zerumbet* (35).

Table 2 Genera, species, individual number, and diversity indices (H' = Shannon-Wiener Diversity Index and D' = Simpson's Diversity Index) of Zingiberaceae in each study site.

	Study sites	Genera	Species No.	Individual No.	H'	D'
1	Suan Ai waterfall	9	18	887	2.756	0.932
2	Suan Khan waterfall	9	20	868	2.802	0.932
3	Sri Nun waterfall	8	16	788	2.678	0.929
4	Tha Pae waterfall	9	18	653	2.741	0.931
5	Ka Rome waterfall	10	23	1112	3.091	0.948
6	Wang Mai Pak waterfall	7	13	930	2.432	0.904

Table 3 Genera, species, individual number, and diversity indices (H' = Shannon-Wiener Diversity Index and D' = Simpson's Diversity Index) of Zingiberaceae in each habitat.

	Habitats	Genera	Species No.	Individual No.	H'	D'
1	Secondary Forest	7	19	1622	2.555	0.896
2	Bamboo Forest	1	1	228	0.401	0.241
3	Rubber Plantation	8	12	1264	2.118	0.849
4	Mixed Crop Plantation	4	5	1198	1.299	0.698

A similar study of using diversity indices to evaluate species richness and abundance for gingers was done in a forest management unit, Serudong, in Sabah, Malaysia [18]. The area is of high altitude, mountainous, and bordered by Kalimantan in Indonesia. Six plots were established for the study. It was found that the Shannon diversity index was highest in the disturbed area, plot 3 ($H' = 2.5$). However, the diversity of gingers in Serudong was found to be lower than that of many other forest reserves in Sabah [18]. The low diversity of gingers in Serudong was accounted for by the presence of infertile heath soil and by its high altitude (700 - 1300 m). The higher the altitude, the lower diversity of gingers is found [12,18]. The reasons given for the highest diversity index in the disturbed area is that the logging or disturbing activities in this infertile area could actually increase soil fertility (from rotting tree branches) and open up space for light and precipitation. Many gingers grow well only in open, wet and humid conditions. This scenario, however, does not imply that the disturbed area of infertile soil could carry gingers beyond that of forests of fertile soils [18]. This key point is demonstrated in this present study. The Shannon diversity indices suggest that fertile soil of secondary forest at the least disturbed Ka Rome waterfall possesses a higher diversity of gingers ($H' = 3.091$) than that of the most disturbed Wang Mai Pak waterfall ($H' = 2.432$). In general, all sites in this study which are also lower in altitude (70 - 402 m) compared to the Serudong sites show higher values of diversity indices than that of Serudong [18].

Zingiberaceae distribution

Eleven species are commonly found in all study sites. At least 14 species are limited in distribution, because they were found in only one study site (Table 1). Ten species are classified in the least concern group, following IUCN Red List and Thai Red List assessment [17].

Three *Alpinia* species were found in secondary forest, rubber plantation, and mixed crop plantation, and were distributed in altitudes between 70 - 235 m. *Alpinia mutica* was reported in Klong Kan, Klong Tha Thon, Klong Yod Num, and Sunanta waterfall of Khao Nan National Park, at altitudes between 90 - 350 m [12] and was recently found in the secondary forest of Ka Rome waterfall at altitudes of 235 m. *Alpinia siamensis* is a cultivated species, and is generally found in all study sites. *Alpinia zerumbet* was reported in Huay Kaewand of Khao Nan National Park at an altitude of 160 m [12] and was recently found in Sri Nun waterfall at altitudes of 70 - 93 m.

Five *Amomum* species and 2 varieties were found in all habitats, and were distributed at altitudes between 70 - 324 m. *Amomum aculeatum* was reported in Huay Lake, Khao Nan National Park, at an altitude of 350 m [12], and was recently found in Suan Ai waterfall, Khao Luang National Park, at an altitude of 214 m. *Amomum testaceum* was found in Ka Rome waterfall at an altitude between 135 - 315 m, and is a rare plant following the IUCN Red List and Thai Red List assessment [17]. *Amomum uliginosum* was reported in Klang Kai, Huay Kaew, Klong Kan, Klong Tha Ton, Huay Lak, Klong Lum Pan, Klong Yod Num, and the Sunata waterfall of Khao Nan National Park, at altitudes between 90 - 500 m [12], and was recently found in all study sites at altitudes between 135 - 324 m. *Amomum rivale* was found in secondary forest at altitudes between 209 - 270 m. *Amomum villosum* var. *xanthiodes* was found in the secondary forest, rubber plantation, and mixed crop plantation of Suan Khan waterfall at altitudes between 70 - 135 m. *Amomum villosum* var. *villosum* was found in the bamboo forest of Suan Khan waterfall at altitudes between 93 - 136 m.

Five *Boesenbergia* species were found in secondary forest and rubber plantation, and were distributed in altitudes between 70 - 315 m. Three *Boesenbergia* species: *Boesenbergia basispicata*, *Boesenbergia curtisii* and *Boesenbergia longipes* are rare plants following IUCN Red List and Thai Red List assessment [17]. *Boesenbergia basispicata* was found in the secondary forest of Ka Rome waterfall at altitudes between 270 - 315 m. Only a clump of *Boesenbergia curtisii* was found in the rubber plantation of Suan Khan waterfall at an altitude 109 m. *Boesenbergia longipes* was found in the rubber plantation of Tha Pae waterfall at altitudes of 200 - 265 m. *Boesenbergia rotunda* is a cultivated species and was commonly found in all study sites.

Three *Curcuma* species were distributed in altitudes between 70 - 135 m. *Curcuma aurantiaca* was reported in Ranong province [19] and was recently found in the rubber plantations of Suan Ai waterfall and Suan Khan waterfall at altitudes between 70 - 135 m. *Curcuma longa* and *Curcuma zedoaria* are cultivated species and were commonly found in all study sites.

Only one species of *Elettariopsis*, *E. curtisii* was found in this study. It was reported in Kanchanaburi province [20], Nakhon Si Thammarat province; the Sunanta waterfall of Khao Nan National Park, and the Krung Ching waterfall of Khao Luang National Park, at altitudes between 350 - 500 m [12] and was recently found in all study sites at altitudes between 70 - 315 m.

Four *Etilingera* species were found in all habitats and were distributed in altitudes between 70 - 402 m. *Etilingera elatior* is a cultivated species. *Etilingera fulgens* was reported in Klong Kan and Huay Lak of Khao Nan National Park at altitudes between 200 - 300 m [12] and was recently found in the secondary forests of Ka Rome waterfall and Wang Mai Pak waterfall of Khao Luang National Park at altitudes between 315 - 332 m. *Etilingera littoralis* was commonly found in all study sites at altitudes between 135 - 402 m. *Etilingera subterranea* was reported in Klong Kan of Khao Nan National Park at altitudes between 260 - 300 m [12] and was recently found in the Suan Khan waterfall, Tha Pae waterfall, and Wang Mai Pak waterfall of Khao Luang National Park at altitudes between 135 - 327 m. *Etilingera* aff. *littoralis* (Form 1) was found in the secondary forest of Ka Rome waterfall at altitudes between 218 - 327 m. *Etilingera* aff. *littoralis* (Form 2) was found in secondary forest and in mixed crop plantation at an altitude of 327 m.

Four *Globba* species were found in secondary forest and rubber plantation and were distributed at altitudes between 70 - 315 m. *Globba pendula* was reported in the Sunanta waterfall of Khao Nan National Park at altitudes between 90 - 200 m [12] and recently found in all study sites of Khao Luang National Park at an altitude of 70 m, except at Wang Mai Pak waterfall. *Globba schomburgkii* was found in the rubber plantation of Sri Nun waterfall at an altitude of 70 m. Only one clump of *Globba* sp.1 was found in the secondary forest of Ka Rome waterfall at an altitude of 316 m. *Globba* sp.2 was found in all habitats at an altitude of 70 m.

Only one cultivated species of *Hedychium*, *H. coronarium* was found in all study sites at altitudes between 70 - 135 m.

Only one *Kaempferia*, *K. pulchra* was found in this study. It was reported in 10 provinces, Phitsanulok, Tak, Nong Khai, Saraburi, Chantaburi, Kanchanaburi, Prachuap Khiri Khan, Chumphon, Surat Thani, Krabi, and Nakhon Si Thammarat [12,19-21]. In Nakhon Si Thammarat province, *K. pulchra* was reported in Huay Kaew of Khao Nan waterfall at altitudes between 150 - 200 m [12] and was recently found in the Ka Rome waterfall of Khao Luang National Park at altitudes between 135 - 315 m.

Six *Zingiber* species were found in all habitats except bamboo forest and were distributed at altitudes between 70 - 402 m. *Zingiber gramineum* was found in the rubber plantation of Sri Nun waterfall at an altitude of 70 m. *Zingiber spectabile* was found in secondary forest at altitudes between 135 - 235 m. *Zingiber officinale* is a cultivated species. *Zingiber zerumbet* was reported in Klong Klai, Huay Kaew, and Huay Lak of Khao Nan National Park at altitudes between 90 - 200 m [12] and was recently found in all study sites of Khao Luang National Park at altitudes between 70 - 402 m. *Zingiber newmanii* was reported in Klong Klai, Klong Kan, Klong Lum Pan, and Krung Ching waterfall at altitudes between 150 - 300 m [12] and was recently found in all study sites of Khao Luang National Park at altitudes between 134 - 402 m.

Key to Zingiberaceae species in Khao Luang National Park

Key to *Alpinia* species

- 1 Bract present, bracteole tubular, leaf abaxially glabrous *A. siamensis*
Bract absent, bracteole open to base, leaf abaxially hairy 2
- 2 Inflorescence drooping, bracteole glabrous..... *A. zerumbet*
Inflorescence erect, bracteole hairy..... *A. mutica*

Key to *Amomum* species

- 1 Fruit smooth, labellum spreading *A. testaceum*
Fruit echinate or spiny, labellum convolute or hooded 2
- 2 Labellum convolute, tip bilobed *A. aculeatum*
Labellum hooded, tip entire or slightly divided 3
- 3 Bract red, flower parts red, labellum yellow *A. rivale*
Bract brown, flower parts white, labellum white 4
- 4 Leaf abaxially hairy, fruit green when mature *A. villosum* var. *xanthioides*
Leaf abaxially glabrous, fruit red to purple when mature..... 5
- 5 Inflorescence 3-many flowered, infructescence 5 - 10 fruits..... *A. uliginosum*
Inflorescence 2-3 flowered, infructescence 2 - 4 fruits. *A. villosum* var. *villosum*

Key to *Boesenbergia* species

- 1 Inflorescence lateral, later may terminal *B. basispicata*
Inflorescence terminal 2
- 2 Labellum spreading, anther opening poricidal *B. curtisii*
Labellum saccate, anther opening longitudinal 3
- 3 Flower pink, anther crest present *B. rotunda*
Flower white or yellow, anther crest absent 4
- 4 Flower white with red dots, lateral staminode oblong..... *B. longipes*
Flower transparent yellow with red dots, lateral staminode obovate.. *B. plicata*

Key to *Curcuma* species

- 1 Coma bract green to white *C. longa*
Coma bract pink 2
- 2 Anther spur present, leaf hairy..... *C. zedoaria*
Anther spur absent, leaf glabrous..... *C. aurantiaca*

Key to *Etilingera* species

- 1 Peduncle raised well above ground, long, 0.6 - 1 m..... 2
Peduncle embedded in ground, short..... 3
- 2 Sterile bracts spreading or recurved, leaf abaxially pale green..... *E. elatior*
Sterile bracts erect, leaf abaxially red green *E. fulgens*
- 3 Labellum red with white margin basally, recurved *E. subterranea*
Labellum whole red or with yellow margin, spreading..... 4
- 4 Labellum length 1-5 cm, anther angled 5 - 15 degree with filament..... *E. littoralis*
Labellum length 5-10 cm, anther angled 45 - 80 degree with filament..... 5
- 5 Anther length 1/2 of labellum length, labellum red..... *E. aff. littoralis* (Form 2)
Anther length 1/3 of labellum length, labellum pinkish red... *E. aff. littoralis* (Form 1)

Key to *Globba* species

- 1 Anther appendages 4, inflorescence pendent..... *G. schomburgkii*
Anther appendages 2, inflorescence erect..... 2
- 2 Anther appendages white, broadly attached, forward pointed..... *Globba* sp.1
Anther appendages yellow, basally attached, backward pointed 3

- 3 Calyx yellowish orange, anther orange.....*G. pendula*
- Calyx purple, anther orange with purple edge.....*Globba sp.2*

Key to *Zingiber* species

- 1 Peduncle procumbent, spike red when flowering.....*Z. newmanii*
- Peduncle erect, spike green or yellow when flowering2
- 2 Spike ovoid-globose, peduncle hairy.....*Z. gramineum*
- Spike fusiform, peduncle glabrous.....3
- 3 Spike length 15 - 20 cm, labellum dark purple mottled..... *Z. spectabile*
- Spike length 6 - 15 cm, labellum red or cream.....4
- 4 Labellum red, bracteole elliptic-oblong.....*Z. officinale*
- Labellum cream, bracteole ovate.....*Z. zerumbet*

Phenology

Most gingers in this study produced flowers between June to November (**Figure 3**). Nine species bloomed in the hot season (February to April) i.e. *Alpinia mutica*, *Alpinia zerumbet*, *Amomum testaceum*, *Amomum aculeatum*, *Curcuma zedoaria*, *Etilingera fulgens*, *Kaempferia pulchra*, *Zingiber newmanii* and *Zingiber spectabile*. At least 19 species bloomed in the rainy season (May to July and October to December) (**Table 1**).

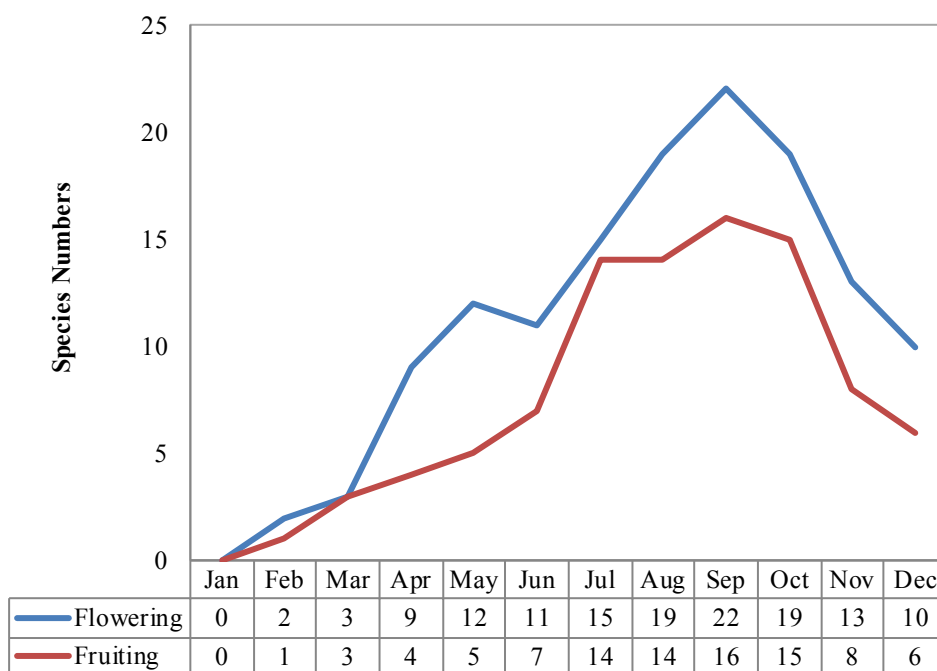


Figure 3 Phenology range of 35 Zingiberaceae taxa in Khao Luang National Park.

Traditional uses

Most gingers in this study grow naturally in the different habitats, and their properties are important in traditional herbal medicines. Some ginger species are also commonly cultivated for their use as spices, dyes and vegetables. Data obtained from villagers and folks indicated that Zingiberaceae plants in the park are really useful. Twenty nine plants (78 %) were used in this study. Most ginger plants were used as medicine, drink, food, and ornaments with percentages of 48, 31, 19, and 2, respectively (**Figure 4**). Eight species have no report on their uses, *Boesenbergia basispicata*, *Curcuma aurantiaca*, *Globba pendula*, *Globba schomburgkii*, *Globba* sp.1, *Globba* sp.2, *Etilingera subterranea*, and *Zingiber gramineum*. All documented plants uses are shown in **Table 4**.

Table 4 Usefulness of Zingiberaceae plants in southern part of Khao Luang National Park and medicinal preparation modes for specific aliments.

No	Species	Usefulness			Medicinal preparation modes				Aliments
		Food	Drink	Ornament	Poultices	Decoctions	Raw plants	Tinctures	
1	<i>Alpinia mutica</i> Roxb.	-	Fr	-	-	Rh	Fr	-	Na, Vo
2	<i>Alpinia siamensis</i> K.Schum.	Rh	Rh	-	Rh	Rh	-	-	St, He
3	<i>Alpinia zerumbet</i> (Pers.) Burt & R.M.Sm.	-	Ps, Fr	-	Le	Rh	-	Fr	Fl, Ca, Sd
4	<i>Amomum aculeatum</i> Roxb.	-	Rh, Le	-	-	Rh, Le	Fr	-	St, He, Ca
5	<i>Amomum rivale</i> Ridl.	-	Rh	-	-	Rh	Fr	-	Cl, Ab, Sd
6	<i>Amomum testaceum</i> Ridl.	-	Fr	-	-	Fr	Fr	Fr	Fl, Ca
7	<i>Amomum uliginosum</i> J.König	-	Rh	-	-	Rh	Fr	-	Ca, He
8	<i>Amomum villosum</i> var. <i>xanthioides</i> (Wall. ex Bak.) T.L.Wu & S.J.Chen	-	Rh, Le	-	Le	Rh, Le	Fr	-	Ca, Ib
9	<i>Amomum villosum</i> var. <i>villosum</i>	-	Rh, Le	-	-	Rh, Le	Fr	-	St, Ca
10	<i>Boesenbergia basispicata</i> K.Larsen ex Sirirugsa	-	-	-	-	-	-	-	-
11	<i>Boesenbergia curtisii</i> (Bak.) Schltr.	Rh	Rh	-	-	Rh	-	-	Sd
12	<i>Boesenbergia longipes</i> (King & Prain ex Ridl.) Schltr.	-	Rh	-	-	Rh	-	-	Fe
13	<i>Boesenbergia plicata</i> (Ridl.) Holtt.	-	Rh	-	-	Rh	-	-	Sn, Sd
14	<i>Boesenbergia rotunda</i> (L.) Mansf.	Rh	-	-	-	-	-	-	Sd
15	<i>Curcuma aurantiaca</i> Zijp.	-	-	-	-	-	-	-	-
16	<i>Curcuma longa</i> L.	Rh, Sh, Yle	-	-	Rh	-	-	-	Sk
17	<i>Curcuma zedoaria</i> (Christm.) Rosc.	Rh	-	-	Rh	-	-	-	Sd, Sk
18	<i>Elettariopsis curtisii</i> Bak.	-	Rh	-	Le	Rh	-	-	Sn, Ib
19	<i>Etilingera elatior</i> (Jack) R.M.Sm.	-	-	In	-	-	-	-	Ca, Sd
20	<i>Etilingera fulgens</i> (Ridl.) C.K.Lim.	-	-	In	-	-	-	-	Ca, Sd
21	<i>Etilingera littoralis</i> (J.König) Giseke	Sh	Rh, Ps	-	-	Rh	Sh	-	St, So, Co

No	Species	Usefulness			Medicinal preparation modes				Aliments
		Food	Drink	Ornament	Poultices	Decoctions	Raw plants	Tinctures	
22	<i>Etilingera subterranea</i> (Holt.) R.M.Sm.	-	-	-	-	-	-	-	-
23	<i>Etilingera</i> aff. <i>littoralis</i> (Form 1)	Sh	Rh, Ps	-	-	Rh	Sh	-	St, So, Co
24	<i>Etilingera</i> aff. <i>littoralis</i> (Form 2)	Rh, Sh	Rh	-	-	Rh	Sh	-	St
25	<i>Globba pendula</i> Roxb.	-	-	-	-	-	-	-	-
26	<i>Globba schomburgkii</i> Hook.f.	-	-	-	-	-	-	-	-
27	<i>Globba</i> sp.1	-	-	-	-	-	-	-	-
28	<i>Globba</i> sp.2	-	-	-	-	-	-	-	-
29	<i>Hedychium coronarium</i> J.König	-	Rh	-	-	Rh	-	-	St
30	<i>Kaempferia pulchra</i> Ridl.	-	Rh	-	-	Rh	-	-	Ca, St, Fe
31	<i>Zingiber gramineum</i> Noronha ex Blume	-	-	-	-	-	-	-	-
32	<i>Zingiber newmanii</i> Theilade & Mood	Sh, YIn	Rh	-	-	Rh	-	-	St, Sd
33	<i>Zingiber officinale</i> Rosc.	Rh	Rh	-	-	Rh	-	-	Ca, St, Sd, Co
34	<i>Zingiber spectabile</i> Griff.	YIn	Rh	-	-	Rh	-	-	St, Ca
35	<i>Zingiber zerumbet</i> (L.) Sm.	Sh	-	-	-	-	-	-	Sd, Ca

Plant Parts: Rh = Rhizome, Ps = Pseudostem, Sh = Leave shoot, Le = Leave, In = Inflorescence, Fr = Fruit, Y = Young
 Aliments: Na = Nausea, Vo = Vomit, St = Stomachache, He = Headache, Fe = Fever, Co = Cold, Cl = Colic, Sk = Skin disease, Ib = Insect bite, So = Sore throat, Sd = Stimulant
 Digestion, Sn = Stimulant nerve, Ab = Abdominal pain, Ca = Caminative, Fl = Flatulence

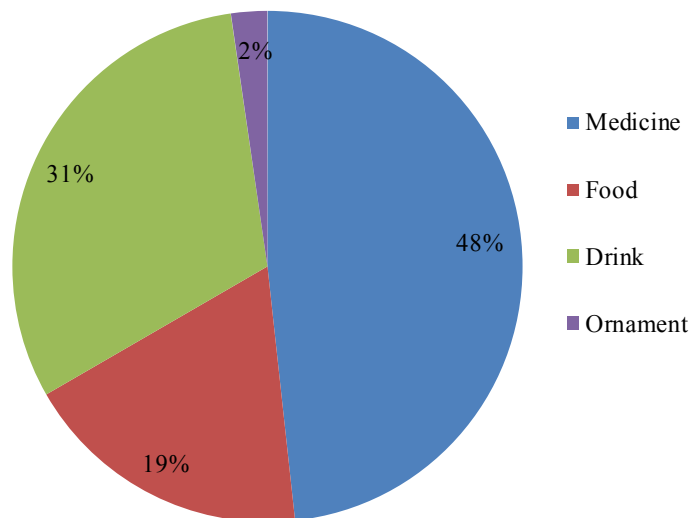


Figure 4 Percentage of Zingiberaceae usefulness.

Four forms of herbal medicines prepared from ginger plants can be recognized, decoction (53 %), raw plants (26 %), poultices (16 %), and tinctures (5 %) (**Figure 5**). The highest medicinal preparation was decoction, which was prepared mainly from the rhizomes, leaves and fruits of *Amomum aculeatum*, *Amomum villosum* var. *xanthioides* and *Amomum villosum* var. *villosum*. The second highest medicinal preparation was raw plants, which mostly used the leave shoots and fruits of *Etlingera elatior*, *Etlingera fulgens* and *Amomum* species. Poultices were prepared mainly from the rhizomes and leaves of *Alpinia zerumbet*, *Elettariopsis curtisii* and *Alpinia siamensis*. Tinctures preparation was extracted from the fruits of *Alpinia zerumbet* and *Amomum testaceum*.

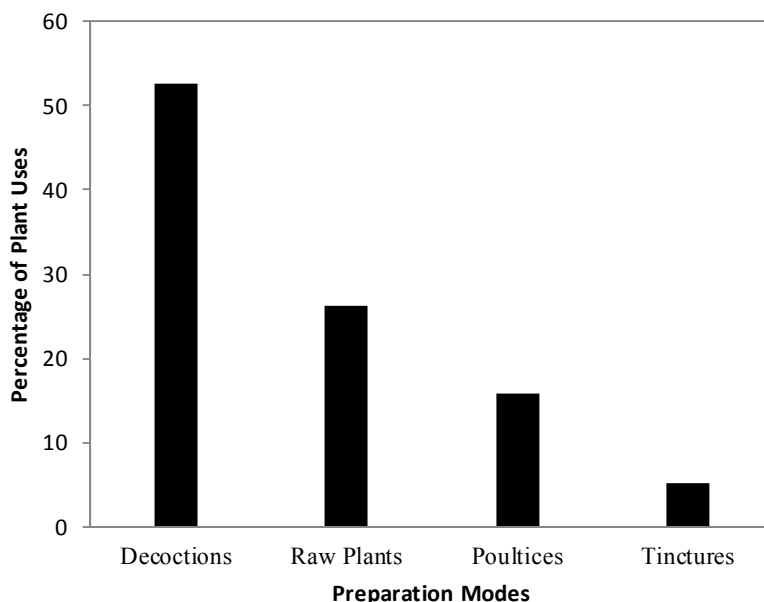


Figure 5 Percentage of medicinal preparation modes of Zingiberaceae plants. *Decoction*: aqueous extract of plant material by boiling. *Raw plant*: specific part of the plant either taken orally or applied locally. *Poultices*: grinded and applied locally. *Tinctures*: aqueous extract of plant material by alcohols.

Conclusions

Thirty-four species, including 2 varieties, of Zingiberaceae were found from 6 waterfalls of the southern part of Khao Luang National Park during March 2011 - March 2012. Four species were unidentified, *Etlingera* aff. *littoralis* (Form 1), *Etlingera* aff. *littoralis* (Form 2), *Globba* sp.1 and *Globba* sp.2. Endemic species for Khao Luang national park, *B. basispicata* and *Z. newmanii*, found in this study and in our previous study [12], are probably still in good condition. Widespread and abundant species, not cultivated, found in this study were *Elettariopsis curtisii*, *Etlingera littoralis*, *Globba pendula*, *Globba* sp.2, and *Z. newmanii* (**Table 4**).

Ka Rome waterfall showed the highest species number of Zingiberaceae plants, with 23 species and 10 genera ($H' = 3.091$, $D' = 0.948$), because the area is least disturbed. Wang Mai Pak waterfall showed the lowest species number of Zingiberaceae plants, with 13 species and 7 genera ($H' = 2.432$, $D' = 0.904$) because most areas are disturbed by villagers, and have been changed into rubber plantation and mixed crop plantation.

The highest species number of Zingiberaceae plants (51 %) were mostly found in secondary forest, and showed the highest species number of Zingiberaceae plants, with 21 species in 8 genera ($H' = 2.555$, $D' = 0.896$). Bamboo forest showed the lowest species number of Zingiberaceae plants, with one species

($H' = 0.401$, $D' = 0.241$), because the habitat was found only at one site, Suan Khan waterfall, in this study.

Zingiberaceae plants in the park were distributed at altitudes between 70 - 402 m. Sixteen species were found in low elevations (below 200 m). Eleven species were found in high elevations (above 200 m). Eight species were generally found in all elevations. Twenty-seven plants (77 %) were used in this study. Most ginger plants were used as medicine, drink, food, and ornaments, with percentages of 48, 31, 19, and 2, respectively.

Two important points can be made concerning conservation of gingers or, in general, plant diversity and its habitats, in this study. First, in low altitude areas with fertile soil, such as in many preserved areas in Thailand, habitat protection should be given the highest priority. No, or the least, disturbance from man may be the best solution for a higher diversity and a healthier ecosystem. Secondly, knowing the benefits of his natural resources, man must then realize their value and conserve them. Many gingers are cultivated by the locals because of their direct value, either in the form of medicine, drink, food, or ornaments. It seems that these species, at least in near future, will not face any threat of extinction.

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References

- [1] WJ Kress, LM Prince and KJ Williams. The phylogeny and a new classification of the gingers (Zingiberaceae): evidence from molecular data. *Am. J. Bot.* 2002; **89**, 1682-96.
- [2] OG Petersen. *Musaceae, Zingiberaceae, Cannaceae, Marantaceae*. In: A Engler and K Prantl (eds.). *Die Natürlichen Pflanzenfamilien*. Vol II, 1st ed. Verlag von Wilhelm Engelmann, Leipzig, Germany, 1889, p. 1.
- [3] K Schuman. *Zingiberaceae*. In: A Engler (ed.). *Das Pflanzenreich IV*. Engelmann, Leipzig, 1904, p. 64-88.
- [4] RE Holttum. The zingiberaceae of the Malay Peninsula. *Garden. Bull. Singapore* 1950; **13**, 1-249.
- [5] BL Burtt and RM Smith. Tentative keys to the subfamilies, tribes and genera of the Zingiberales. *Notes Roy. Bot. Garden Edinb.* 1972; **31**, 171-6.
- [6] RM Smith. Synoptic keys to the genera of Zingiberaceae pro parte. *Roy. Bot. Garden Edinb. Depart. Publ.* 1981; **28**, 1-28.
- [7] K Larsen and S Larsen. *Gingers of Thailand*. Queen Sirikit Botanic Garden, Chiang Mai, Thailand, 2006, p. 1-184.
- [8] P Sirirugsa. Three new species and one new combination in *Boesenbergia* (Zingiberaceae) from Thailand. *Nord. J. Bot.* 1987; **7**, 421-5.
- [9] C Maknoi and P Sirirugsa. New records of Zingiberaceae from Southern Thailand. *Nat. Hist. Siam. Soc.* 2002; **50**, 225-37.
- [10] C Maknoi, P Sirirugsa and K Larsen. New records of *Curcuma* L. (Zingiberaceae) in Thailand. *Thai. For. Bull. Bot.* 2005; **33**, 71-4.
- [11] C Picheansoonthon and P Mookamul. Two new *Calokaempferia* taxa (Zingiberaceae) from northeastern Thailand. *Folia Malaysiana* 2004; **5**, 69-80.
- [12] N Kittipanangkul and C Ngamriabsakul. Zingiberaceae diversity in Khao Nan and Khao Luang National Park, Nakhon Si Thammarat, Thailand. *Walailak J. Sci. & Tech.* 2008; **5**, 17-27.

- [13] C Ngamriabsakul. *Caulokaempferia sirirugsae* sp. nov. (Zingiberaceae) from southern Thailand. *Nord. J. Bot.* 2008; **26**, 325-8.
- [14] J Mayoe. A new species of *Geostachys* Ridl. (Zingiberaceae) from Southern Thailand. *Taiwania* 2010; **55**, 8-12.
- [15] ASTV Manager Southern Thailand, Available at: <http://www.manager.co.th/South/ViewNews.aspx?NewsID=9550000117885>, accessed September 2012.
- [16] I Theilade. A synopsis of the genus *Zingiber* (Zingiberaceae) in Thailand. *Nord. J. Bot.* 1999; **19**, 389-410.
- [17] S Saensouk. Endemic and rare plants of ginger family in Thailand (*in Thai*). *KKU Res. J.* 2011; **16**, 306-30.
- [18] J Gobilik. Diversity of gingers at Serudong, Sabah, Malaysia. *J. Trop. Bio. Cons.* 2008; **4**, 15-21.
- [19] P Sirirugsa. 1999, Thai Zingiberaceae: Species Diversity and Their Uses, Available at: <http://www.iupac.org/symposia/proceedings/phuket97/sirirugsa.html>, accessed January 2012.
- [20] K Suvandech and D Sobchaloem. Systematic studies of Zingiberaceae in Thong Pha Phum forest, Kanchanaburi province. *In: Proceedings of the 44th Kasetsart University Annual Conference: Engineering, Architecture, Natural Resources and Environmental Management.* Bangkok, Thailand, 2004, p. 572-9.
- [21] S Saensouk. The family Zingiberaceae in Nong Kam Koh, Muang district, Nong Khai province, Thailand. *In: Proceedings of the 33rd Congress on Science and Technology of Thailand.* Nakhon Si Thammarat, Thailand, 2005, p. 1-4.