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FLORISTIC COMPOSITION OF A SEASONAL DRY EVERGREEN FOREST AT HUAI KHA KHAENG WILDLIFE SANCTUARY, WESTERN THAILAND

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ABSTRACT

We describe the floristic composition of a seasonal dry evergreen forest located in Huai Kha Khaeng Wildlife Sanctuary (HKK), Uthai Thani Province, based on a census of all trees ≥ 1 cm dbh in a 50-ha plot. The plot included 248 species, 164 genera and 60 families of trees and shrubs. The floristic composition of this forest is comparable to published reports for other seasonal evergreen forests in Thailand in both overall diversity and patterns of dominance. The HKK plot was less species rich than other large-scale plots in peninsular Malaysia (820 species), Sarawak (1194 species) and Panama (306 species); however, when species diversity was compared on a per-stem basis, the HKK plot was as diverse as the aseasonal lowland forests in Malaysia. The floristic structure of the plot was notable for its high number of species with very low density. Approximately 60% of the species had densities of < 1 individual ha^{-1}. Shade intolerant species indicative of disturbance were relatively common in the 50-ha plot. Many of the long-lived shade intolerants had senescent populations, suggesting the influence of a large-scale catastrophic disturbance in the past. Senescent populations of several species typical of mixed deciduous and deciduous dipterocarp forests suggest that the forest at the study site may not have previously been seasonal dry evergreen forest.

Key words: diversity, disturbance, Huai Kha Khaeng, permanent plot, Thailand

INTRODUCTION

In 1995 the first census of a large-scale permanent forest dynamics plot in seasonal dry evergreen forest at the Huai Kha Khaeng Wildlife Sanctuary (HKK) was completed. The primary objective of the census was to establish baseline data on the structure and composition of an area of Thai forest undisturbed by humans in recorded history (BUNYAVEJCHEWIN *ET AL.*, 1999).

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In an earlier paper (BUNYAVEJCHEWIN *ET AL.*, 2001) we described the stand structure of the seasonal dry evergreen forest and addressed three questions relevant to forest ecology in southeast Asia: (1) Is the forest at HKK representative of seasonal evergreen forests of continental southeast Asia? (2) Does the structure of the seasonal dry evergreen forest differ from that of other lowland tropical forest types? and (3) Is there evidence that the stand has experienced severe disturbance in the past? Based on analysis of the stand structure we concluded that the HKK forest was representative of seasonal dry evergreen forests in the region, but that it differed from the aseasonal equatorial lowland tropical forests in its paucity of trees in the 1–5 cm size class. In addition, the structural data provided strong indirect evidence that a catastrophic disturbance had impacted the forest sometime in the past 200 years.

In this paper we examine the same three questions stated above, but instead of using the stand structure data we examine the questions within the context of the floristic composition of the seasonal dry evergreen forest. This paper closely parallels that of KOCHUMMEN *ET AL.* (1990) which describes the floristic structure of the first census of a similar forest dynamics plot in at the Pasoh Forest Reserve in peninsular Malaysia.

SITE DESCRIPTION AND METHODS

The study site is located in the Huai Kha Khaeng (huai = "stream") Wildlife Sanctuary at 15° 40' N latitude and 9° 15' E longitude in Uthai Thani Province, west-central Thailand, approximately 300 km northwest of Bangkok. The sanctuary encompasses nearly 2300 km^2 of the Huai Kha Khaeng watershed. The topography consists of broad river valleys and moderately steep ridges running north-south. The sanctuary contains a mosaic of four forest types: seasonal evergreen forest, mixed deciduous forest, dry dipterocarp forest, and hill evergreen forest. The study site is located in an area of seasonal evergreen forest. Elevation within the study plot ranges from 525 to 575 m above sea level. Mean annual rainfall is 1475 mm (1983–1993). The climate is monsoonal with a rainy season from May to October and a dry season from November to April (in which mean monthly rainfall is <100 mm). The extent and severity of the dry season is variable. Some years have sporadic rainfall during the dry season, while others have little or no rain for the entire dry season. Mean July temperature is 27°C; mean January temperature is 19°C. Minimum recorded temperatures are as low as 12°C and maximum temperatures as high as 38°C. Maximum daily relative humidity drops below 98% only during the height of the dry season in March and April. Minimum daily relative humidity varies between 40% and 60% except during the dry season, when it is frequently less than 20%.

The FDP is a 50-ha rectangle 1 km long (north-south axis) and 0.5 km wide (east-west). The enumeration included all free-standing woody plants ≥1 cm dbh. Each tree was measured, mapped to plot coordinates, and identified following a standard protocol (MANOKARAN *ET AL.*, 1990; CONDIT, 1997). All data are stored in a Microsoft Access database to facilitate data retrieval and manipulation. Taxonomy and nomenclature follow BUNYAVEJCHEWIN *ET AL.* (2000), which includes a complete list of all species and voucher specimens.

RESULTS AND DISCUSSION

Diversity

The HKK 50-ha plot included 80,640 trees of 248 species in 164 genera and 61 families. This is relatively species-poor when compared to the mega-diverse aseasonal tropical forests of Southeast Asia. An identical plot at the Pasoh Forest Reserve in peninsular Malaysia contained 329,000 trees of 820 species, 294 genera and 78 families (KOCHUMMEN *ET AL.*, 1990). The species diversity was 3.2 times higher at Pasoh than at HKK; however, the diversity per tree was 1.3 times higher at HKK (Table 1). In a slightly larger (52-ha) plot at the Lambir Hills National Park in Sarawak the total number of individuals was 361,000, including 1194 species. The Lambir plot had 4.6 times the number of species present at HKK, but only slightly greater diversity on a per-tree basis (Table 1).

In the seasonal tropics there are two other large-scale plots that are, perhaps, better suited for comparison to the HKK plot. The 50-ha plot on Barro Colorado Island (BCI), Panama, is the oldest of the 50-ha plots, being established in the early 1980s. At BCI the original census included 238,000 individuals of 306 species in 61 families (HUBBELL & FOSTER, 1986). The total species richness at BCI was 1.2 times that at HKK; however, when diversity is assessed on a per-tree basis, the 50-ha plot at HKK was 2.5 times higher than BCI (Table 1). The other large-scale plot in the seasonal tropics is located in southern India at the Mudumalai Wildlife Sanctuary. The Mudumulai 50-ha plot had 16,899 individuals from 74 species of 27 families (CONDIT *ET AL.*, 1996). The total species diversity was 3.5 times higher at HKK than at Mudumalai, although the per-tree diversity was 1.4 times higher at Mudumalai (Table 1).

Table 1. Diversity patterns at five large-scale tropical forest dynamics plots.

Plot	Individuals (N)	Species (N)	Species per tree (x 10^3)	Proportion of rare species[a]
Mudumalai, India	16,899	74	4.38	34.0
HKK, Thailand	80,640	248	3.08	64.5
BCI, Panama	238,000	306	1.29	36.0
Pasoh, Pen. Malaysia	329,000	820	2.49	33.3
Lambir Hills, Sarawak	369,126	1194	3.24	33.5

[a]Proportion of species with population densities of <1 individual/ha.

There are few data for comparison with other seasonal dry evergreen forests in Thailand. BUNYAVEJCHEWIN (1986, 1999) enumerated all trees ≥4.5 cm dbh in two 1-ha plots of seasonal evergreen forest in Sakaerat, Nakhon Ratchasima. The two Sakaerat plots were floristically distinct, principally with respect to the primary dipterocarp canopy species: one plot was dominated by *Hopea ferrea*, while the other was dominated by *Shorea henryana*. To compare the HKK plot with the Sakaerat plots the number of species for individuals ≥4.5 cm dbh was tallied for each of the 50 hectares. The mean and standard deviation were calculated from the distribution of species counts. In terms of overall diversity the HKK plot is very similar to the Sakaerat plots. At HKK the mean number of species in one hectare was 82.3 (SD = 9.3); whereas at Sakaerat the mean number of species (averaged from two censuses) was 70.5 and 105.5 for the *Hopea ferrea* and *Shorea henryana* stands, respectively. In addition, the relatively high dominance of one dipterocarp species was a common feature of all three forests. At HKK *Hopea odorata* dominated the canopy; whereas at Sakaerat either *Hopea ferrea* or *Shorea henryana* dominated.

Relative Abundance of Species

Croton roxburghii (syn. *C. oblongifolius*; Euphorbiaceae) was the most abundant species in the plot, accounting for 11.4% of all trees. The 20 most common tree species accounted for 71% of the total number of trees and 48% of the basal area in the 50-ha plot. For trees over 10 cm dbh the most abundant species was *Polyalthia viridis* (Annonaceae), which accounted for 11.8% of the total. The most abundant tree species over 30 cm dbh was *Miliusa lineata* (syn. *Saccopetalum lineatum*; Annonaceae) which accounted for 12.5% of all trees (larger than 30 cm dbh).

The seasonal dry evergreen forest at HKK differs from the mixed lowland forests of aseasonal southeast Asia in the relative abundance of the most common species. In the mixed forests the most common species typically have low densities (RICHARDS, 1996). For example, the most abundant species in the 50-ha plot at Pasoh, which is located in mixed lowland rain forest, was *Xerospermum noronhianum* (Sapindaceae), but it only accounted for 2.5% of all trees in the plot (KOCHUMMEN *ET AL.*, 1990). In contrast, among the neotropical forests that have been well studied, the most common species often occur at relatively high density. For example, at the BCI 50-ha plot more than 40,000 individuals of the treelet *Hybanthus prunifolius* (Violaceae) were included in the first census—approximately 16% of all censused stems greater than 1 cm dbh. The floristic structure of the seasonal dry evergreen forest at HKK, therefore, appears to be more consistent in terms of relative abundance with the seasonal forests of central America than the aseasonal forests of Southeast Asia.

An important aspect of the floristic structure of the seasonal dry evergreen forest at HKK is the great abundance of species represented by extremely small populations. Twenty-eight species are represented by single individuals within the plot, 75 species are represented by 5 or fewer individuals, and 160 species have population densities of less than 1 individual per ha (i.e., less than 50 individuals in the plot). When compared with other large-scale plots, the proportion of species with less than 1 individual per hectare at the HKK plot is extremely high (64%). In fact, the proportions for four other plots ranging across an order of magnitude in diversity and from highly seasonal to aseasonal are remarkably similar, ranging from 33 to 36% of the community (Table 1).

Familial Composition of the Tree Flora

A relatively small proportion of the total flora dominated the density and basal area of the plot. Similar patterns occurred at the family level. The relative importance of taxonomic families to number of species, number of stems, and basal area is shown in Table 2.

Table 2. Family rankings for all trees 1 cm dbh or greater in the 50-ha forest dynamics plot at Huai Kha Khaeng Wildlife Sanctuary, western Thailand.

Family	Species	%	Rank	Density	%	Rank	BA	%	Rank
Euphorbiaceae	31	12.06	1	15,243	18.95	2	97.87	6.45	4
Moraceae	18	7.00	2	193	0.24	27	79.73	5.25	6
Leguminosae	16	6.23	3	2,542	3.16	9	42.60	2.81	11
Rubiaceae	13	5.06	4	4,899	6.09	4	5.15	0.34	23
Sapindaceae	11	4.28	5	9,892	12.30	3	83.88	5.53	5
Meliaceae	10	3.89	6	1,799	2.24	11	50.75	3.34	10
Annonaceae	9	3.50	7	16,787	20.87	1	293.84	19.36	2
Lauraceae	9	3.50	7	4,575	5.69	5	118.57	7.81	3
Rutaceae	9	3.50	7	2,776	3.45	8	10.46	0.69	20
Verbenaceae	8	3.11	10	378	0.47	22	7.81	0.51	22
Flacourtiaceae	8	3.11	10	207	0.26	25	3.32	0.22	27
Dipterocarpaceae	7	2.72	12	2,879	3.58	7	333.26	21.95	1
Lythraceae	7	2.72	12	1,095	1.36	16	54.28	3.58	9
Anacardiaceae	7	2.72	12	589	0.73	20	27.09	1.78	14
Sterculiaceae	7	2.72	12	1,152	1.43	15	14.04	0.92	17
Ebenaceae	6	2.33	16	4,223	5.25	6	62.66	4.13	7
Ulmaceae	6	2.33	16	22	0.03	44	0.80	0.05	37
Burseraceae	4	1.56	18	156	0.19	30	16.81	1.11	16
Bignoniaceae	4	1.56	18	1,899	2.36	10	13.58	0.89	18
Myrtaceae	4	1.56	18	673	0.84	18	11.77	0.78	19
Myrsinaceae	4	1.56	18	987	1.23	17	1.53	0.10	31
Celastraceae	4	1.56	18	92	0.11	33	0.31	0.02	47
Tiliaceae	3	1.17	23	93	0.12	32	2.50	0.16	28
Guttiferae	2	0.78	24	1,575	1.96	12	35.77	2.36	12
Rosaceae	2	0.78	24	116	0.14	31	3.60	0.24	24
Combretaceae	2	0.78	24	13	0.02	48	3.42	0.22	26
Melastomataceae	2	0.78	24	402	0.50	21	1.63	0.11	30
Oleaceae	2	0.78	24	46	0.06	39	1.12	0.07	33
Simaroubaceae	2	0.78	24	43	0.05	40	0.85	0.06	36
Fagaceae	2	0.78	24	88	0.11	34	0.79	0.05	38
Apocynaceae	2	0.78	24	51	0.06	37	0.68	0.04	40
Dilleniaceae	2	0.78	24	6	0.01	49	0.65	0.04	41

Table 2 (continued).

Family	Species	%	Rank	Density	%	Rank	BA	%	Rank
Alangiaceae	2	0.78	24	218	0.27	24	0.58	0.04	43
Myristicaceae	2	0.78	24	49	0.06	38	0.55	0.04	44
Araliaceae	2	0.78	24	3	0.00	50	0.23	0.02	49
Theaceae	2	0.78	24	2	0.00	54	0.14	0.01	50
Juglandaceae	2	0.78	24	1	0.00	57	0.07	0.00	52
Datiscaceae	1	0.39	38	1,548	1.92	13	61.39	4.04	8
Irvingiaceae	1	0.39	38	164	0.20	28	28.01	1.85	13
Aceraceae	1	0.39	38	618	0.77	19	24.36	1.60	15
Sonneratiaceae	1	0.39	38	41	0.05	41	10.38	0.68	21
Polygalaceae	1	0.39	38	195	0.24	26	3.42	0.23	25
Opiliaceae	1	0.39	38	161	0.20	29	1.82	0.12	29
Rhizophoraceae	1	0.39	38	35	0.04	42	1.30	0.09	32
Magnoliaceae	1	0.39	38	17	0.02	45	1.11	0.07	34
Boraginaceae	1	0.39	38	224	0.28	23	1.04	0.07	35
Santalaceae	1	0.39	38	59	0.07	36	0.73	0.05	39
Elaeocarpaceae	1	0.39	38	15	0.02	46	0.65	0.04	42
Solanaceae	1	0.39	38	1,192	1.48	14	0.46	0.03	45
Capparidaceae	1	0.39	38	77	0.10	35	.38	0.03	46
Aquifoliaceae	1	0.39	38	14	0.02	47	0.28	0.02	48
Staphylliaceae	1	0.39	38	25	0.03	43	0.09	0.01	51
Hypericaceae	1	0.39	38	3	0.00	50	0.04	0.00	53
Proteaceae	1	0.39	38	2	0.00	54	0.04	0.00	54
Styracaceae	1	0.39	38	3	0.00	50	0.04	0.00	55
Connaraceae	1	0.39	38	3	0.00	50	0.02	0.00	56
Olacaceae	1	0.39	38	1	0.00	57	0.01	0.00	57
Podocarpaceae	1	0.39	38	1	0.00	57	0.01	0.00	58
Lecythidaceae	1	0.39	38	1	0.00	57	0.00	0.00	59
Urticaceae	1	0.39	38	1	0.00	57	0.00	0.00	60
Symplocaceae	1	0.39	38	2	0.00	54	0.00	0.00	61

The Euphorbiaceae ranked 1st in number of species, 2nd in abundance of trees, and fourth in basal area. At the Pasoh 50-ha plot the Euphorbiaceae showed an almost identical pattern of dominance. The significance of this family in the forests of Southeast Asia is well known; however, because the majority of species occur in the understory and midstory, they have often been overlooked in studies that have relatively large minimum sampling diameters (e.g., 10 cm dbh).

The Moraceae ranked 2nd in number of species and 6th in basal area, but were only 27th in abundance. The majority of the Moraceae species in the plot were *Ficus*, many of which were hemiepiphytic (i.e., strangling). The high rank in basal area is due to two factors: (1) inclusion of the host trees diameter when measuring strangling figs, and (2) large buttresses that are too tall to measure above. The pattern of high diversity and low density is common for *Ficus*.

The Annonaceae tied for 7th in species diversity, but were ranked 1st and 2nd for number of stems and basal area, respectively. The Annonaceae are an important component of the forest canopy, although many of the most common trees in the understory and midstory are also from the family.

The Dipterocarpaceae dominate the upper canopy and emergent layers of the evergreen lowland forests of Southeast Asia. At the 50-ha plot the Dipterocarpaceae ranked 12th in diversity and 7th in abundance, but were ranked 1st for basal area. Only 3.6% of the stems on the 50-ha plot were dipterocarps; however, they accounted for 21% of the stand's basal area, indicating the key role the family plays in the overall forest structure.

Other important families include the Lauraceae and Sapindaceae, which ranked fifth and 7th in number of species, 5th and 3rd in number of stems, and 3rd and 5th in basal area, respectively. Both families were major components of the midstory and lower canopy of the forest. The Datiscaceae was represented by a single species, *Tetrameles nudiflora*, tying it for last in number of species; however, *Tetrameles* was quite common and achieved great size in the forest. Consequently, the Datiscaceae ranked 13th in abundance and 8th in basal area.

Overall, the patterns of diversity and abundance at the familial level were consistent with other lowland forests of Southeast Asia.

Species Indicative of Disturbance

The floristic composition of the 50-ha plot at HKK suggests that the seasonal dry evergreen forest has been strongly influenced by past disturbances. Both short-lived and long-lived shade intolerants are common at HKK suggesting that disturbance has played an important role in structuring the forest at a variety of temporal scales. Short-lived shade intolerant tree species—those that are commonly found along roadsides and disturbed land—include *Macaranga siamensis, Melia azederach, Mallotus paniculatus, Oroxylum indicum,* and *Trema orientalis*. These species regenerate exclusively in the large treefall gaps that occur in the forest. Large individuals of these species are occasionally found alone or in small groups in the forest, indicating the site of an old gap.

Long-lived shade intolerant species are also common in the 50-ha plot. Examples include *Duabanga grandiflora, Anthocephalus cadamba, Tetrameles nudiflora, Toona ciliata, Ailanthus triphysa,* and *Pterocymbium javanicum*. A relatively consistent feature of the long-lived secondary species is that their populations consist mostly of large individuals and regeneration is scant. This suggests that that (1) they are senescent, and (2) the conditions under which they became established have not occurred for many decades. Based on an analysis of the stand structure of the 50-ha plot, BUNYAVEJCHEWIN *ET AL.* (2001) concluded that there was strong indirect evidence that the present stand of seasonal dry evergreen forest was initiated by a catastrophic disturbance within the past 200 years. The floristic structure of the 50-ha plot provides further indirect evidence of a severe disturbance at the stand scale occurring in past centuries.

Another interesting facet of the floristic structure of the 50-ha plot that may be indicative of historic disturbances is the occurrence of 'senescent' populations, consisting mostly of large trees and lacking regeneration, of species that are typical of either the mixed deciduous or deciduous dipterocarp forest types. Examples include *Pterocarpus macrocarpus*, for which 10 of the 13 individuals in the plot were greater than 30 cm dbh; *Terminalia bellirica*, for which 11 of the 13 individuals in the plot were greater than 30 cm dbh; and *Shorea siamensis*, for which the sole individual was 65 cm dbh and had the gnarled and tumescent bole typical of relict *S. siamensis* in dry dipterocarp stands elsewhere in the sanctuary.

BAKER (2001), based on tree ring reconstructions and diameter growth-based age estimates, hypothesized that the disturbance occurred approximately 150 years ago. The floristic evidence presented here is consistent with the hypothesis of a catastrophic disturbance initiating a new development trajectory dominated by seasonal dry evergreen forest species. There is no clear evidence of what type of disturbance may have occurred. However, several types of disturbances have been documented in continental Southeast Asia, including fire, windstorms, and human disturbance.

Fire has been present in the seasonal forests of Southeast Asia for at least 10,000 yr (STOTT, 1988). In the past decade, low-intensity ground fires have burned through the 50-ha plot three times (S. Bunyavejchewin, personal observation). Such fires tend to create single- or multiple-tree fall gaps and would not produce the conditions typical of a stand replacing disturbance. It is possible that in the past fire frequency may have been lower allowing a build-up of litter and dense ladder fuels that would have created more intense forest fires. However, there is no evidence of a residual charcoal layer in the soil in or around the 50-ha plot (P. J. Baker, personal observation) as might be expected following a catastrophic, stand-replacing fire.

Intense wind storms have severely damaged forests in temperate and tropical regions (RICHARDS, 1996; OLIVER & LARSON, 1996). There is anecdotal evidence of destructive wind storms in the vicinity. Tornadoes or line squalls flattened a strip of forest several km^2 in extent in an area of Burma approximately 60 km to the east of HKK (Anonymous, 1929; 1932). A 10-ha block of forest in HKK was knocked over by windstorms in 1987 (T. Prayurasiddhi, personal communication).

Another potential disturbance mechanism is human action. Human-induced disturbances such as logging or agriculture could potentially lead to the conditions necessary for establishment of the *Hopea* stand. Because of the lack of anthropological and archaeological evidence in the area, it is difficult to assess the potential for large-scale human-induced disturbance in recent centuries. However, Burmese and Thai military troops moved through the region during conflicts in the late 1500s and the late 1700s (WYATT, 1984). Land clearance for timber or temporary rice cultivation may have preceded such mass movements; however, the main routes traveled by the invading armies were to the south (Three Pagodas

Pass, Kanchanaburi Province) and north (Mae Sot, Tak Province) of HKK (WYATT, 1984).

The floristic evidence also suggests that the forest that existed prior to the disturbance may have been more similar in composition to the present day mixed deciduous forest found at HKK than to the seasonal dry evergreen forest currently on the plot. Stochastic factors such as the timing of relatively wet years, mast fruiting events, or periods of lower fire frequency may have facilitated the switch in composition from deciduous to evergreen dominated forest following the disturbance.

Finally, the floristic evidence also suggests that less intense disturbances have impacted—and continue to impact—the forest on the 50-ha plot.

CONCLUSION

Three questions were posed at the outset of this study: (1) Is the forest at HKK representative of seasonal evergreen forests of continental southeast Asia? (2) How does the seasonal dry evergreen forest differ floristically from other lowland tropical forest types? and (3) Is there evidence that the stand has experienced severe disturbance in the past? Based on the floristic evidence from the 50-ha plot the seasonal dry evergreen forest at HKK does appear to be similar in overall diversity and patterns of dominance to other seasonal evergreen forests in continental Southeast Asia. When compared with other tropical lowland evergreen forests, the HKK plot is relatively low in overall diversity, being most closely comparable to other seasonal tropical forests. However, when diversity is compared on a per-tree basis the HKK plot is as rich as the most diverse aseasonal forests in Southeast Asia. In terms of overall familial composition, the HKK plot is typical of Southeast Asian forests. Finally, indirect evidence from floristic composition supports the hypothesis that the seasonal dry evergreen forest at HKK has been greatly influenced by disturbances during the past several decades and centuries.

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