Structure and Dynamics in Seasonal Dry Evergreen Forest in Northeastern Thailand[1]

ลักษณะโครงสร้าง พลวัต และความผันแปรของป่าดิบแล้ง ในภาคตะวันออกเฉียงเหนือของประเทศไทย

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บทคัดย่อ

ปัจจุบันการศึกษาพลวัตในป่าโซนร้อน จะทำการศึกษาจากแปลงตัวอย่างถาวรขนาดใหญ่ โดยเลือกให้เป็นตัวแทนของป่าชนิดนั้น ๆ เนื่องจากการจำแนกชนิดป่าในโซนร้อนจะจำแนกอย่างกว้าง ๆ ซึ่งจะมีความแตกต่างทั้งลักษณะโครงสร้าง รูปแบบพลวัต และองค์ประกอบพืชพรรณ ซึ่งความผันแปรนี้ไม่สามารถรวมอยู่ในแปลงตัวอย่างเพียงแปลงเดียวได้ เพื่อชี้ให้เห็นถึงปัญหาดังกล่าว ได้ทำการวางแปลงตัวอย่างถาวรขนาด 1 เฮกแตร์ จำนวน 2 แปลงในปี พ.ศ. 2530 ในป่าดิบแล้งที่สถานีวิจัยสิ่งแวดล้อมสะแกราช ในปี พ.ศ. 2540 ได้ทำการวัดข้อมูลซ้ำ ทำการเปรียบเทียบรูปแบบการเกิดทดแทน การตาย และการเจริญเติบโตระหว่างแปลง แปลงที่มีไม้ตะเคียนหินเป็นพันธุ์ไม้เด่น มีพลวัตค่อนข้างคงที่ มีอัตราการตาย การเกิดทดแทน และการเจริญเติบโตค่อนข้างต่ำ ในทางตรงกันข้ามแปลงที่มีไม้เคี่ยมคนองเป็นพันธุ์ไม้เด่น มีพลวัตมาก โดยมีอัตราการเจริญเติบโต การตาย และการเกิดทดแทนสูง หากพลวัตของทั้งสองแปลงยังคงดำเนินไปเหมือนเช่นในปัจจุบัน ในอนาคตลักษณะโครงสร้างและองค์ประกอบพันธุ์ไม้ ของทั้งสองแปลงจะแตกต่างกันมากยิ่งขึ้น ถึงแม้แปลงตัวอย่างถาวรขนาดใหญ่ ซึ่งถือเป็นแปลงตัวแทนของชนิดป่า จะสามารถเจาะลึกถึงพลวัตของป่าได้ละเอียด แต่ก็มีจุดด้อยในแง่ไม่สามารถครอบคลุมความผันแปรของป่าชนิดนั้น ๆ ได้

คำหลัก: สังคมย่อย, การเจริญเติบโต, อัตราการตาย, การขึ้นทดแทน, แปลงตัวอย่างถาวร

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ABSTRACT

Studies of tropical forest dynamics have often been bases on one large-scale permanent plot, representative of a given forest type. Broad classifications of tropical forest types are expected to include a wide range of stand structures, dynamics patterns and species compositions – a range which cannot be represented in a single plot. To demonstrate this problem two 1-ha permanent plots, dominated by *Hopea ferrea* and *Shorea henryana* (both Dipterocarpaceae), respectively, were established in 1987 in seasonal dry evergreen forest at the Sakaerat Environmental Research Station in northeastern Thailand. In 1997 the plots were remeasured as to patterns of recruitment, mortality and growth. The *Hopea* plot was relatively static with low mortality, recruitment and growth. The *Shorea* plot was very dynamic with high rates of growth, mortality and recruitment. If the current trends continue, the plots are likely to further diverge. Even if the study of a large forest plot provides a good insight into tropical forest dynamics, it is necessary to consider the entire local pattern of variation.

Keywords: Forest type, Growth, Mortality, Permanent plot, Recruitment.

INTRODUCTION

Classification in tropical forests typically recognizes relatively broad forest types based on general structural or climatic variables. For example, ‘tropical lowland evergreen rain forest’ covers huge areas in southeast Asia and the Malay Archipelago (Whitmore, 1985). Yet, given the large number of tree species in the forests, variation in soils and other site variables and differences in historic disturbance regimes, marked variation in stand structure and species composition within the same forest type will be inevitable (Condit, 1996; He *et al.,* 1997).

Due to the lack of annual rings in many tropical tree species, the study of tropical forest dynamics has relied heavily on the use of permanent plot data. Recently the number of permanent plots in the tropics has increased rapidly. This is especially true for large-scale plots such as the 50-ha plots at Barro Colorado Island, Panama, and the Huai Kha Khaeng Wildlife Sanctuary, Thailand. The developing network of large permanent plots has facilitated comparisons of structure and dynamics between forests of different countries, climates (e.g. monsoonal vs. evermoist) and biogeographic regions. However, due to the relatively high financial and logistic investment required for the initial census, large permanent plots are rarely replicated within a forest type. In continental southeast Asia there are few large permanent plot studies that have been replicated within a single forest type. Replicated permanent plots within a forest type might provide insight into the nature of variation within the forest type and thus foster a better understanding of the dynamics and composition of the forest type.

Seasonal dry evergreen forest is widespread throughout Thailand, particularly in regions with 4-6 dry months and no more than 1,200 mm total annual rainfall (Ashton, 1990). In southern Thailand seasonal dry evergreen forest is found on sandstone ridges; in the north of Thailand seasonal dry evergreen forest is restricted to riparian galleries in regions of deciduous forests. Throughout the rest of the Thailand seasonal dry evergreen forest is found as part of the landscape forest mosaic. Seasonal dry evergreen forest is very important both economically, due to the high value of the timber species, and ecologically because of its unique biotic communities.

Seasonal dry evergreen forest is closed canopy forest in which the main canopy is predomainantly evergreen forest trees with scattered individuals of deciduous trees (Santisuk, 1988). Dipterocarps form an important component of the canopy, although the diversity of dipterocarp species is less in seasonal dry evergreen forests than in the tropical evergreen rain forest of peninsular Thailand (Santisuk, 1988). Mean canopy height is ca. 35-40 m. while these general descriptions are well documented, detailed data on the variation of stand structure and composition within seasonal dry evergreen forest is rare.

In this paper I report on the results of a replicated permanent plot study in the seasonal dry evergreen forest of continental southeast Asia. The principle objectives of the study were to (1) describe the structure and dynamics of seasonal dry evergreen forest and (2) to describe the nature of variation within the seasonal dry evergreen forest type based on a comparison two permanent 1-ha plots.

STUDY SITE AND METHODS

The Sakaerat Environmental Research Station is located in Nakhon Ratchasima Province, NE Thailand, ca. 180 km northeast of Bangkok at $14^{o}\,30^{/}$ N, $101^{o}\,56^{/}$ E. The station administers 81 km^2 of reserved forest of which 29.5 km^2 is seasonal dry evergreen forest (Wacharakitti *et al.*, 1980). The climate at Sakaerat is monsoonal with a mean annual rainfall of 1,240 mm. During the dry season, from November to April, mean monthly rainfall is typically < 40 mm. Mean annual temperature is 26.2° C. The geology and soils are characterized by Triassic and Cretaceous sandstone formations from the *Phra wihan* formation of the *Korat* group, overlain by shallow to moderately deep red-yellow podzols (Moorman and

Rojanasoonthon, 1972; Bos and Thundunn, 1968). The area consists of low rolling hills divided by flat valleys.

At Sakearat two distinct seasonal dry evergreen forest associations occur, characterized by their dominant species. One is dominated by *Hopea ferrea,* the other by *Shorea henryana.* Previous research (Bunyavejchewin, 1986) has shown that the *Hopea ferrea* type prefers level sites, has a lower species richness and a greater tendency towards monodominance. The *Shorea henryana* type prefers slopes and has higher species richness. The upper canopy of the *Hopea ferrea* type is generally more continuous than that of the *Shorea henryana* type.

In 1987 two 1-ha plots (100 m x 100 m) were established in the seasonal dry evergreen forest at Sakearat, one in a stand of the *Hopea ferrea* type and one in a stand of the *Shorea henryana* type. The *Hopea* plot is flat and has a mean elevation of 460 m. a.s.l. The *Shorea* plot has a mean slope of 19° and a mean elevation of 540 m. a.s.l. Several rocky outcrops occurred on the *Shorea* plot, suggesting thinner soils.

Each study plot was subdivided into 100 10m x 10 m subplots. All trees larger than 4.5 cm DBH were measured, mapped to plot coordinates and identified to species. In 1997 both plots were recensused. Analysis of species composition and forest structure are based on the 1987 census unless otherwise stated. Estimated mortality rates are based on a logarithmic loss model:

$$\text{Tree mortality} = (\text{In}N - \text{In}S) / t \qquad (1)$$

Where N is the initial tree number and S is the number of trees surviving t yr.

Table 1. Species richness, density (stem/ha) and basal area (m^2/ha) of trees > 4.5 cm DBH in 1987 and 1997. ↓ = disappeared; ↑ = appeared.

	Species richness				Density		Basal area	
	/87	/97	↓	↑	/87	/97	/87	/97
Hopea ferrea	76	65	16	4	1,168	1,115	29.1	29.4
Shorea henryana	100	111	8	19	1,356	1,499	29.8	28.9

RESULTS

Species richness and composition

The number of species in each plot at each census are shown in Table 1. The 20 most common species for each forest type ate shown in Table 2. In the *Hopea* plot the 20 most common species accounted for 80.1% of the total density and 80.1% of the plot basal area. In the *Shorea* plot they accounted for 43.7% of the total density and 52.5% of the plot basal area. There were 38 species represented by a single individual in the *Hopea* plot in 1987 (50% of the total number of species in the plot) and 29 species in 1997 (45%). In the *Shorea* plot 24 species (24%) were represented by a single individual in 1987, while 29 species (26% of the total) had only one individual in 1997.

Changes in number of tree species over the 10-yr period showed opposite trends in the two plots. In the *Hopea* plot many species recorded in the 1987 census were not present in 1997. In the *Shorea* plot fewer species disappeared but many more appeared (Table 1). Local extinction of species within each plot is most likely the result of stochastic fluctuations. All of the 24 species that became locally extinct in the two plots had either one (21 spp.) or two (3 spp.) individuals in the 1987 census.

Forest structure

Initial tree density and basal area were slightly lower in the *Hopea* plot (Table 1). By 1997 the basal area of the *Hopea* plot had increased slightly and that in the *Shorea* plot decreased somewhat. In the *Hopea* plot ca. 90% of the gain in basal area can be attributed to growth of surviving trees. In the *Shorea* plot growth of surviving trees accounted for 76% of the basal area increase with recruitment of new stems accounting for the rest. The basal area estimates for the seasonal dry evergreen forest plots in 1987 and 1977 (ca. 30 m^2/ha;) are at the lower end of the range of basal areas reported in permanent plots in other tropical forests (23.0-65.4 m^2/ha; Swaine *et al*., 1987).

Size class distributions are typical of natural forest regenerating from seed, with high stem counts in the smaller size classes. The most obvious difference between the plots was the difference in diameter distribution of the dominant dipterocarps. In the *Hopea* plot *Hopea ferrea* had many smaller stems and decreasingly few large trees while *Shorea henryana* in the *Shorea* plot had relatively few smaller stems (Figure 1). If individuals <10 cm DBH are excluded from the analysis, *Shorea henryana* had an approximately normal diameter distribution (Shapiro-Wilks $W = 0.976$, $p = 0.73$, NS) with mean diameter of 50.4 (SD = 22.37, $n = 30$).

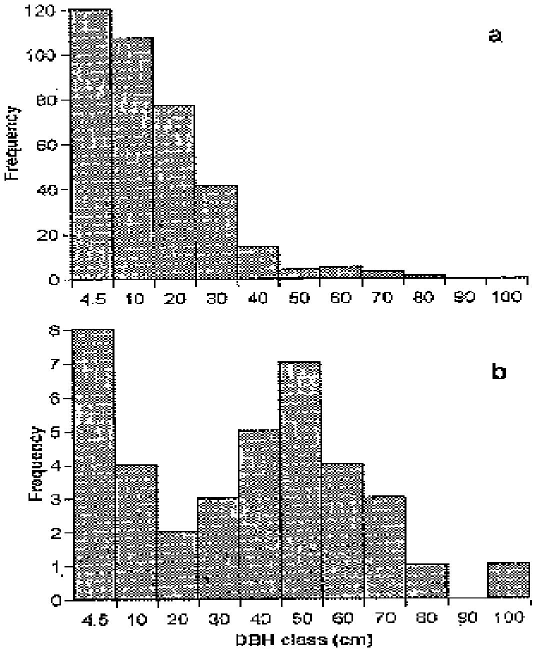

Figure 1. Diameter distribution of the dominant dipterocarp in each study plot at Sakaerat; **a**. *Hopea ferra*; **b.** *Shorea henryana*

Mortality and recruitment

At the 1997 census 294 stems had died and 437 stems had been recruited in the *Shorea* plot; the corresponding figures for the *Hopea* plot are 162 died and 109 new. 52% of the mortality in the *Hopea* plot were standing dead trees, vs. 42% in the *Shorea* plot; figures for uprooted trees and trees with broken stems were 22% (*Hopea* plot) and 18% (*Shorea* plot), respectively. The rest of the mortality was associated with missing stems. Death by uprooting or stem breakage was more common in the larger size classes, while dead trees in the small size classes either died standing or were killed by falling trees (Table 3). These results suggest that death of small trees occur from suppression or competition, while the death of larger trees is more likely to be the result of disturbance.

Mortality and recruitment rates were 1.5 %/yr and 0.93 %/yr in the *Hopea* plot and 2.4 %/yr and 3.2 %/yr in the *Shorea* plot. Excluding trees in the smallest size class (4.5-10cm DBH) balanced the mortality and recruitment rates in both plots. Mortality and recruitment of trees >10 cm were 62 and 53 stems in the *Hopea* plot and 106 and 109 stems in the *Shorea* plot. Thus, for trees >10 cm DBH mortality and recruitment rates were 1.1 %/yr and 0.9 %/yr in the *Hopea* plot and 2.4 %/yr and 2.2 %/yr in the *Shorea* plot.

Table 2. Species data for the 1.0 ha plot at Sakaerat Environmental Research Station, NE Thailand. Only data for the 20 most common species are given. The data are enumerated for the period of 1987-1997. DBH = DBH growth (mm/yr); Mor = mortality (%/yr); Rec = recruitment (%yr); C/U = canopy or understorey tree. M = main canpy; U = understorey

	Density (stems/ha)		Basal area (m^2/ha)					
	'87	'97	'87	'97	DBH	Mor	Rec	C/U
***Hopea ferrea* plot**								
Hopea ferrea	372	359	16.25	17.71	1.5	0.75	0.38	M
Hydnocarpus ilicifolius	143	146	1.26	1.27	0.3	0.50	0.70	U
Walsura trichostemon	97	85	0.89	0.72	0.8	2.57	1.03	U
Memecylon ovatum	87	92	0.44	0.45	0.6	2.03	2.41	U
Memecylon fruiticosum	58	45	0.60	0.52	0.6	3.97	1.03	U
Aglaia pirifera	58	73	0.47	0.53	1.0	1.29	3.79	U
Mammea siamensis	43	40	0.74	0.72	0.6	0.98	0.23	U
Shorea henryana	15	14	1.94	1.53	2.1	1.43	0.67	M
Canthium spec.	34	26	0.43	0.36	1.3	3.48	0.59	U
Litsea glutinosa	29	29	0.34	0.36	0.5	0.00	0.00	U
Dialium cochinchinenesis	16	15	1.06	1.26	2.6	0.64	0.00	M
Eugenia grata	13	13	0.62	0.66	1.1	0.80	0.77	U
Grewia paniculata	14	10	0.54	0.38	0.4	3.36	0.00	U
Melodorum fruitcosum	16	14	0.17	0.17	0.7	1.34	0.00	U
Vatica cinerea	14	16	0.34	0.40	1.3	0.00	1.43	M
Linociera microstigma	12	10	0.12	0.10	0.6	2.88	0.00	U
Diospyros spec.	10	8	0.19	0.09	0.7	2.23	0.00	U
Randia wittii	13	12	0.05	0.05	0.4	4.85	3.07	U
Streblus ilicifolius	10	11	0.02	0.03	0.2	1.05	2.00	U
Gonocaryum lobbianum	12	12	0.06	0.07	0.2	0.00	0.00	U
***Shorea henryana* plot**								
Shorea henryana	38	44	7.17	7.38	2.1	0.54	2.10	M
Hydnocarpus ilicifolius	120	113	1.40	1.52	0.9	1.05	0.42	U
Walsura trichostemon	118	163	0.93	1.06	1.6	1.96	5.59	U
Aglaia pirfera	84	111	0.97	0.95	1.9	2.41	5.36	U
Prunus spec.	28	36	2.54	2.92	3.4	0.00	2.86	M
Metadenia trichotoma	64	45	1.11	0.82	0.8	3.52	0.00	U
Memecylon fruiticosum	52	38	0.49	0.41	1.3	4.55	0.96	U
Microdesmis caseariifolia	57	69	0.29	0.34	0.5	3.52	3.33	U
Gonocaryum lobbianum	52	53	0.47	0.49	0.9	1.23	1.35	U
Randia wittii	47	44	0.29	0.27	1.0	3.84	2.55	U
Croton oblongifolius	54	83	0.27	0.43	1.9	5.55	9.63	U
Aporusa frutescens	44	38	0.44	0.43	0.7	2.88	1.14	U
Aglaia chandocensis	45	55	0.24	0.19	1.0	4.39	5.78	U
Litsea verticillata	37	33	0.36	0.18	1.8	5.66	3.24	U
Mangifera spec.	24	27	0.38	0.45	1.6	0.00	1.25	M
Parkia sumatrana	10	15	0.97	0.54	2.7	1.05	6.00	M
Eugenia spec.	12	13	0.71	0.64	1.9	0.87	1.67	M
Antiaris toxicaria	14	12	0.61	0.36	2.0	1.54	0.00	M
Ardisia spec.	27	24	0.10	0.09	0.6	5.88	3.33	U
Memecylon ovatum	22	26	0.17	0.23	1.5	0.46	2.27	U

Table 3. Relative frequency of different mortality factors by DBH size class in the *Hopea ferrea* plot and the *Shorea henyana* plot at Sakaerat.

DBH class (cm)	% broken	% missing	% standing	% uprooted
Hopea ferrea				
4.5 - 10	12.1	19.2	52.5	16.2
11 – 30	8.8	10.5	52.6	28.1
31 – 50	0.0	0.0	50.0	50.0
51 – 70	0.0	0.0	100.0	0.0
71 – 90	0.0	0.0	100.0	0.0
Shorea henryana				
4.5 - 10	12.2	41.0	35.6	11.2
11 – 30	7.8	14.6	49.4	28.1
31 – 50	0.0	0.0	71.4	28.6
51 – 70	0.0	0.0	0.0	100.0
71 – 90	0.0	0.0	50.0	50.0

Although overall size class distributions were comparable between forest types, the mortality rates of the size classes were different both within and between plots (Figure 2). In the *Hopea* plot the middle size classes had the lowest mortality rates and the smallest and largest size classes had the highest mortality rates. In contrast, the *Shorea* plot had low mortality in two of the three largest size classes and high mortality in all of the mid-range size classes. However, the large fluctuations in mortality rate among the larger size classes (>40 cm DBH) may be due to the presence of few large individuals.

In the Sakaerat plots the highest mortality occurred among understorey species. For example, *Croton oblongifolius* and *Ardisia* spec. had mortality rates of 5.5 %/yr and 5.9 %/yr, respectively, in the *Shorea* plot, and *Randia wittii* had a mortality rate of 4.8 %/yr in the *Hopea* plot. A comparison of mortality between the understorey and canopy (Table 2) for the 20 most common species was significant for the *Shorea* plot (one-way ANOVA, P = 0.0002, df = 18), but showed no significant differences in the *Hopea* plot (one-way ANOVA, P = 0.114, df = 18). In the *Shorea* plot the mean annual mortality of the common understorey trees (3.3%) was considerably higher than that of the canopy trees (0.7%).

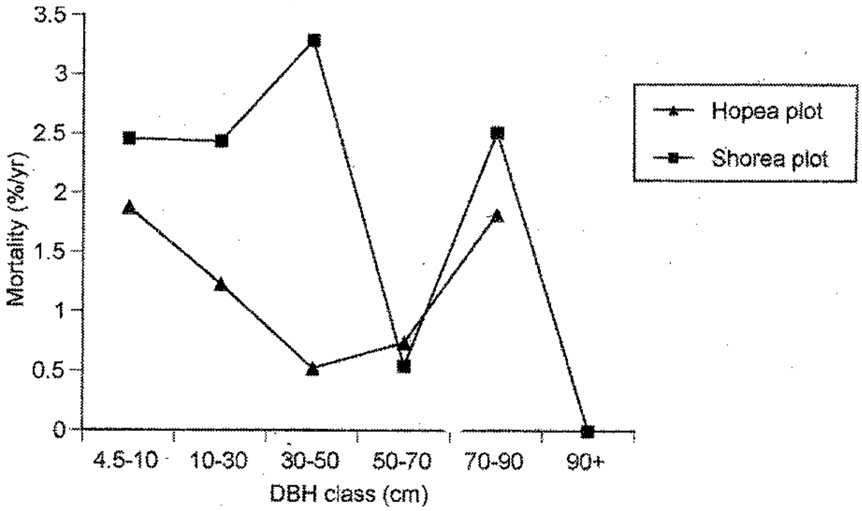

Figure 2. Mortality across size classes for the *Shorea henryana* plot and the *Hopea ferra* plot at Sakaerat

Diameter growth

Mean diameter growth rate was 1.0 mm/yr in the *Hopea* plot and 1.5 mm/yr in the *Shorea* plot; figures for the 20 most common species are shown in Table 2. Mean DBH increment in the *Shorea* plot (1.5 mm/yr) falls within the range for tropical forest — 1.0-7.0 mm/yr (Silva *et al.*, 1989), while the mean annual increment of the *Hopea* plot (1.0 mm/yr) was marginally less.

Species population dynamics

Population density for most species was relatively constant from 1987 to 1997. Of the total number of species, 89% and 79% of the populations increased or decreased over the 10-yr period by less than two individuals in the *Hopea* plot and the *Shorea* plot, respectively (Figure 3). Most species did not exceed the 95% confidence limits of an expected zero net change (Figure 4). In the *Hopea* plot, only seven species exceeded the 95% confidence limits; in the *Shorea* plot, only five species did. If consideration is restricted to the trees > 10 cm DBH, only one species, *Metadenia trichostemon,* was found outside the 95% confidence limits for zero net change and this occurred only for the population in the *Hopea* plot (Figure 4); however, this is most likely the result of the small sample size (*n*=2) for *Metadenia* in the *Hopea* plot.

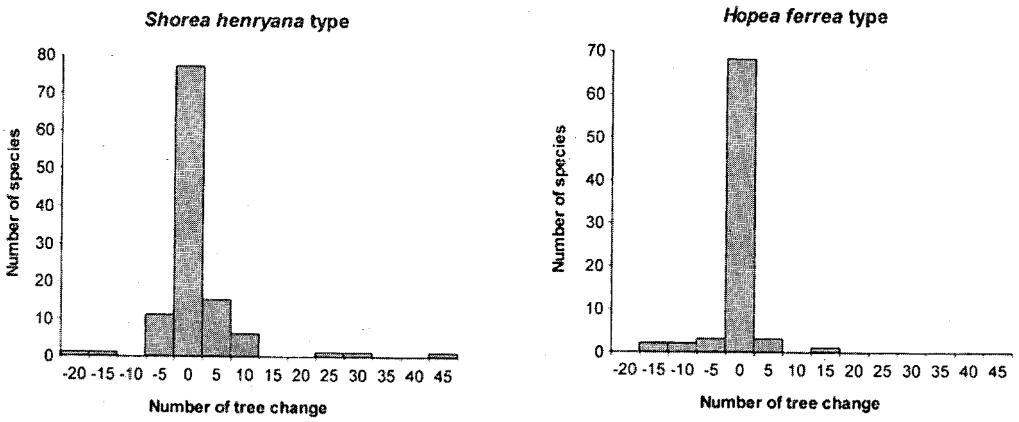

Figure 3. Distribution of change in number of trees over 10 yr for the 100 species in the *Shorea henryana* plot and the 76 species in the *Hopea ferra* plot at Sakaerat.

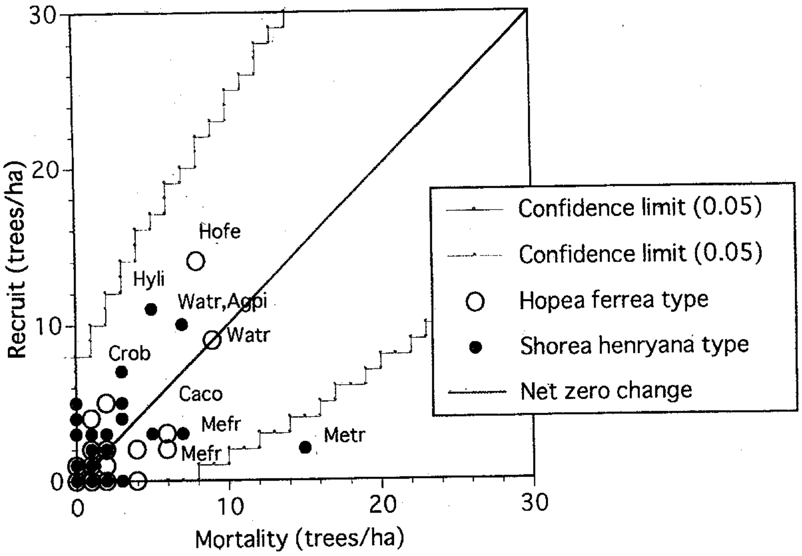

Figure 4. Relationship between total mortality and total ingrowth of trees >10 cm DBH at Sakaerat between 1987 and 1997. Bold line represents zero net population change. Light lines represent 95% confidence intervals. For species abbreviations, see Table 2.

DISCUSSION

In recent years the methodological emphasis in the study of tropical forests has shifted to large-scale permanent forest plots. The 50-ha plot at Barro Colorado Island, Panama, established in 1982, was the first of the 'mega-plots' (Hubbell and Foster, 1983). In the past decade a network of such plots has been established by the Center for Tropical Forest Science (CTFS) and contains at least 15 other plots ranging from 25-52 ha spread throughout the tropical regions of the world. While such large plots provide important baseline data on the ecology of species for which little or no information exists, they require a large initial investment and thus are not often replicated. Consequently, the plots provide no information on the nature of variation within the forest type they 'represent'. When results form such plots are extrapolated and depicted as representative of the forest type as a whole, caution is warranted. The seasonal dry evergreen forest at Sakaerat provides a clear example of this problem. At Sakearat there are at least two distinct variations within the seasonal dry evergreen forest type, one dominated by *Shorea henryana,* the other by *Hopea ferrea.* While structurally and floristically both are seasonal evergreen forest, species composition of the dominant species, as well as stand-level dynamics, differ substantially.

The *Shorea* plot, with higher rates of recruitment, mortality and mean annual increment, is more dynamic than the *Hopea* plot. Site conditions and stand history of the *Shorea* plot may provide a partial explanation for these differences. The *Shorea* plot is located on a hill slope with relatively shallow soils. The drier, thinner soils of the hill sides may increase the likelihood of windthrow among canopy trees (Bunyavejchewin, 1986). The incidence of small gaps typical of windthrow is higher in the *Shorea* plot (S. Bunyavejchewin pers. obs.) and accounts for the more dissected canopy structure (Bunyavejchewin, 1986) when compared to the *Hopea* plot (Kanzaki *et al*., 1994). The higher incident radiation reaching the forest floor in the *Shorea* plot would account for the higher recruitment rate and diameter increment, especially among trees in the smallest size class. The low shade tolerance of *Shorea henryana* and its diameter distribution within the *Shorea* plot suggest that the *Shorea* population (excluding individuals in the smallest size classes) may be a single-age cohort that established after a relatively large disturbance such as a catastrophic wind storm. Observations of *Shorea henryana* seedings have shown that individuals in the forest understorey grow very little, whereas individuals exposed to sunlight in gaps and along road edges grow rapidly (S. Bunyavejchewin pers. obs.). The diameter distribution of *Shorea* is approximately normal with a mean diameter of 50.4 cm. The largest trees are larger than 100 cm in diameter. Such normal diameter distributions have been commonly documented for even-aged cohorts of shade intolerant species in temperate (Oliver, 1978) and tropical forests (Finnegan, 1996). As this cohort of *Shorea henryana* becomes mature and senescent, the rate of gap formation is likely to increase due to the combined effects of tree size and site conditions.

In contrast, the *Hopea* plot has lower mortality, recruitment and mean annual increment than the *Shorea* plot. The plot is largely dominated by *Hopea ferrea*. Kanzaki *et al*. (1994) described a similar *Hopea ferrea* stand in an adjacent plot as monodominant forest. *Hopea ferrea* accounted for 56% of the basal area of the current *Hopea* study plot. The canopy is uniform and more or less unbroken (Bunyavejchewin, 1986; Kanzaki *et al*., 1994). In 2.63 ha of the *Hopea ferrea* forest studied by Kanzaki *et al*. (1994) only 5.9% was in the gap phase and only four gaps were formed in a four year study period, for an estimate annual gap formation rate of 0.0005 ha/ha/yr. Comparable data form an area of *Shorea henryana* forest is not available. *Hopea ferrea* is found in all size classes and appears to be regeneration *in situ.* There is no evidence of past disturbance in the *Hopea* plot from the size or spatial distributions of the species present. The current dynamics of the *Hopea* forest suggest that little change in the structure or composition should be expected in the near future.

If the current patterns of growth, mortality and recruitment continue in the seasonal dry evergreen forest at Sakaerat over the coming decades, the differences in stand structure and dynamics between the two plots will become increasingly obvious. Such variation within a single forest type may be an important determinant of plant and animal diversity within that forest type. It is important to recognize that such differences are inevitable given the broad definitions that exist for tropical forest types - and that these differences are unlikely to be detected using a single 'representative' plot.

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