germination and seedling development (Singh & Singh 1992). In addition, immature seeds are more susceptible to diseases and unfavourable environmental conditions.

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DIPTEROCARP FRUIT DISPERSAL AND SEEDLING DISTRIBUTION

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Saving young regeneration (seedlings and saplings) of commercial timber species during logging operations would greatly further the sustainable management of forests. In context with management of the dipterocarp forests in Malaysia, such an effort may become the key to perpetuating the timber production of the forests, whether using Selective Fellings (e.g. Malaysian Selective Felling) or Regeneration Systems (e.g. Malayan Uniform System, and its modified version). The expense of enrichment planting in both cases may be reduced or eliminated if the seedlings of commercial species are not heavily destroyed during logging.

Conventional logging using tractors and skidders usually causes much damage to the young regeneration (Fox 1969). However, if we know more about their distribution, steps can be taken to protect them. With this in view, we carried out a study to observe the dispersal pattern of fruits, as well as the distribution of seedlings and saplings of dipterocarps.

Although the majority of the dipterocarps bear fruits with wings, they are merely gravity dispersed and fall close to the mother tree. Only on rare occasions are they blown far from the mother tree (Webber 1934). We therefore confined the study to the pattern of fruit dispersal and seedling distribution to a wide circle around the fruiting trees.

The study was carried out in the Sungai Tekam Forest Reserve, Peninsular Malaysia. The area represents a logged hill dipterocarp forest, with a meranti-keruing forest type (Wyatt-Smith 1963). A localized fruiting occurred in the area in June 1987 (Appanah & Rasol 1994). The species chosen for the study were all *Shorea* except for one *Hopea* species. Healthy residuals were chosen, and wedge plots (90° and 25 m radius from base of tree) were laid under the seed shadow of the tree. The 25 m radius was chosen as beyond that few fruits of the tree were found. The wedge was subdivided into 5 m radial sectors. Following initiation of fruit fall, the fruits were collected at weekly intervals and examined for quality. Fruits of other dipterocarp species were not included. Only healthy fruits were counted. One year later, a survey of the seedlings and saplings was done on an adjacent wedge plot of the same shape and size (90° and 25 m radius from base of tree). This time seedlings of all dipterocarp species were included. They were enumerated, identified, and their heights measured. The data from 12 trees were averaged, and multiplied by 4 to estimate for the seed shadow area, a full circle of 25 m radius around a tree.

The fruit dispersal pattern is shown in Figure 1. The frequency of fruits increased gradually with distance from the base of the tree until the 15 - 20 m sector, and declined in the 20 - 25 m sector. No counts were made beyond that distance since the numbers were too low, and usually the areas were shaded by crowns of other trees. Burgess (1970, 1975) too found the same pattern - over 80% of the fruits fell within 40 m. Fox (1972) found a rapid decrease in amount of fruit fall 40 m from the tree. The narrower dispersal distances seen in Jengka could be due to many factors, particularly the extremely poor fruiting season. The average number of fruits in the seed shadow of a dipterocarp tree was estimated at about 5400.

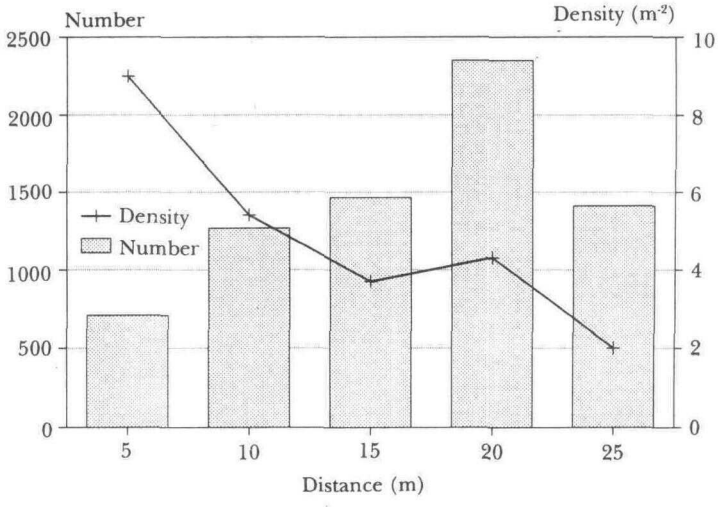

Figure 1. Number and density of fruits under the seed shadow of a dipterocarp residual tree in a logged hill dipterocarp forest. Samples are estimates for a full circle of the seed shadow, derived from 90 ° wedges with 25 m radius: N=12

The pattern in the density of the fruits (frequency over area) differed though (Figure 1). It was highest in the first sector (0 - 5 m), began to decline progressively in the subsequent two sectors, increased somewhat in the 15 - 20 m sector, and dropped abruptly in the last sector (20 - 25 m). The perceptible increase in the density that bucked the downward trend appeared, however, to be not significant. The average density of the fruit crop in the seed shadow (25 m radius) of a dipterocarp tree was about 2.75 m^2.

The results of the seedling survey are shown in Table 1. Under the seed shadow of a mature dipterocarp residual, besides seedlings of the same species, numerous other plant species could be seen, including that of several other dipterocarp species. As many as six species were found under on tree. Sites existed where seedlings of the same species as the mother tree were fewer or even absent compared to other dipterocarp species.

Within the 90° wedge, the number of seedlings ranged from 7 to 48, with an average of 22 (Table 1). Hence, for a full ring around the tree, the numbers can be estimated at between 4 and 220 seedlings and saplings. The average number of seedlings around a large residual tree can be estimated at about 88, and the density about 0.045 m^2.

In general, the frequency of seedlings increased outwards from the base of the tree, reached a peak in the 15 - 20 m segment, and declined sharply in the 20 - 25 m sector (Figure 2). The same pattern held for seedlings belonging to similar species as the mother tree. However, the proportion of these seedlings to others declined outwards from the base of the tree: In the 0 - 5 m sector, the like species comprised 46%, and declined to only 11.6% in the outermost sector. The density of seedlings in the seed shadow of the tree was relatively high (0.055 m^2), it dipped in the second sector (0.037 m^2), then began to increase to a maximum in the 15 - 20 m sector (0.067 m^2), and declined rapidly in the 20 - 25 m sector (0.028 m^2) (Figure 2).

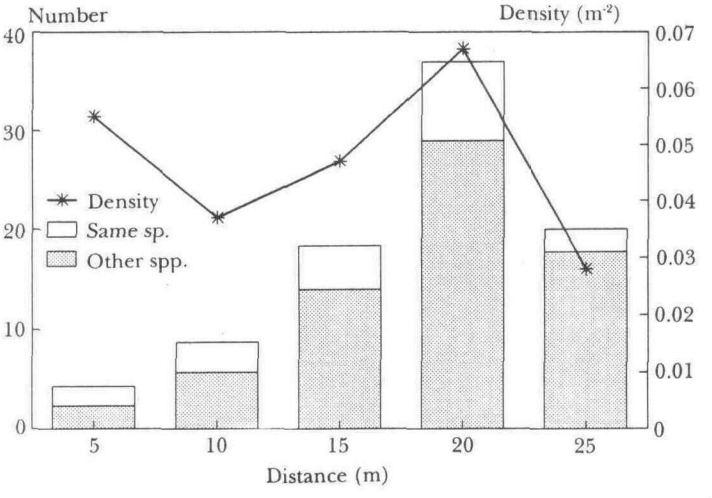

Figure 2. Number and density of all dipterocarp seedlings under the seed shadow of a dipterocarp residual tree in a logged hill dipterocarp forest. Samples are estimates for a full circle of the seed shadow, derived from 90 ° wedges with 25 m radius; N=12

Both the frequency and density of seedlings were high or highest in the 15 - 20 m sector. This pattern appears to reflect that of the seed dispersal, with highest density in this sector. Perhaps seedling survival is optimum at a distance from the mother tree.

Table 1. Percentage frequency and species of dipterocarp seedlings found under the seed shadow of residual trees in a logged hill dipterocarp forest

Mother tree	Seedling species and % frequency									Total frequency
	S. macroptera	*S. pauciflora*	*S. ovalis*	*S. leprosula*	*S. bracteolata*	*S. parvifolia*	*S. lepidota*	*S. acuminata*	*H. pubescens*	
Hope pubescens					71.4	14.3			14.3	7
Shorea macroptera	17.4		8.7	21.7	34.8	13.1	4.3			23
Shorea macroptera	10.0	10.00	10.0	50.0	10.0	10.0				10
Shorea macroptera				50.0	8.3		8.3	33.4		12
Shorea macroptera	90.4	4.8				4.8				21
Shorea macroptera	18.2			18.2	42.4	18.2	3.0			33
Shorea macroptera	33.3	3.0		24.3	12.1	27.3				33
Shorea lepidota	30.3			20.9	9.3	11.6	27.9			43
Shorea leprosula	8.3		8.3	8.3	66.8			8.3		12
Shorea leprosula	40.0				30.0	30.0				10
Shorea leprosula	40.0			30.0	20.0	10.0				10
Shorea parvifolia	47.9			6.3	31.2	4.2	10.4			48
Total										262
Average										21.8

Samples are from 90° wedges with a radius of 25 m.

The greater part of the seedlings growing under the seed shadow of a dipterocarp tree (about 77%) comprised other species, and this became enhanced particularly so in the outer sectors of the tree. This could be expected as the distance from the tree increases. However, what is surprising is that the proximal area, the seed shadow area of a dipterocarp, is in fact swamped by other species of the family. Based on these observations, it cannot be claimed that the mother tree suppresses its own progeny. It can, however, be proposed that the conditions exist which support mixtures than a single species. This should explain why clumps of adult dipterocarps in these forests are rarely dominated by a single species.

Figure 3 shows the size (measured as height) and frequency of seedlings with distance from the base of the tree. The data are pooled from enumerations of 90° wedges from 12 trees. Overall, there are fewer and smaller seedlings close to the tree, and the number and size of seedlings increase with distance to a maximum in the 15 - 20 m sector. In the sector beyond that, a slight decline in frequency is apparent, but not in the height of the seedlings. The biggest seedlings and saplings are found in this zone.

Since the majority and the best seedlings are found in the outer rim circling the tree, this is perhaps the best place for the seedlings' survival and growth. Probably the light factors are more favourable here. During tree felling, these areas are trampled by machine and men. If such activities are kept to the minimum in the area, damage to young regeneration can be kept low. The opening of the crown due to logging may then provide adequate light conditions for rapid regrowth of these rim of valuable dipterocarp seedlings. One procedure that can be adopted to minimize damage in the perimeter around the base of a dipterocarp tree is to prohibit machines from driving to the base of the tree stump to haul logs. They should be bucked and hauled out with cables from a distance, preferably from beyond 30 m from the stump. But truly "low impact" logging methods like sky-line yarding would be most preferable to minimise damage to the seedling crop. No tractor enters the stand and the entire area is free from any soil disturbance. The light breaks in the canopy would be most suitable for the seedling regeneration.

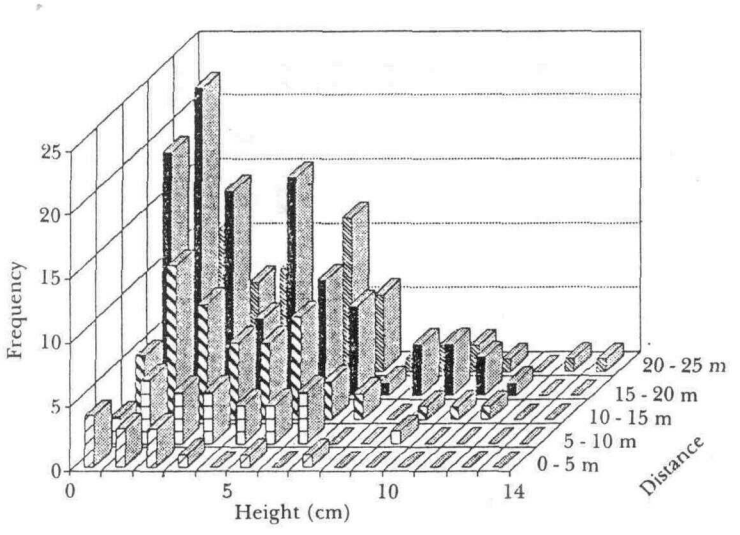

Figure 3. Number and size (height) of dipterocarp seedlings found under the seed shadow of 12 dipterocarp trees. The frequencies in the radial sectors leading away from the base of the tree are also shown. Samples are totals of counts derived from 90° wedges with 25 m radius; N=12 trees.

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