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Response of Woody Species to Anthropogenic Disturbances in Sacred Forests of Northeast India

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ABSTRACT

The response of woody species to anthropogenic disturbances was studied in three forest stands viz., Swer, Nonglang and Nongkrem representing subtropical humid forests of the area. These forest stands were preserved till recently as sacred groves on the basis of religious beliefs. However, during the past decade, some portions of these sacred groves have been disturbed due to product extraction following erosion in religious beliefs. The diversity and regeneration of woody species present in these forests has been studied to assess the response of the species to human disturbance. A total of 114 woody species (^{3}5cm dbh) were identified in the three forests. The species richness in disturbed stands was significantly lower in the disturbed stand (24-26) than the undisturbed stands (60-32). The density also followed a similar trend in Swer and Nonglang forest stands whereas, it increased from 898 stems ha^{-1} in the undisturbed stand to 954 stems ha^{-1} in the disturbed stand at Swer. The basal area of woody species was significantly higher in the undisturbed stands (27 - 62 m^{2}ha^{-1}) than the disturbed stands (3.14 to 58.25 m^{2}ha^{-1}). The distribution of density in different dbh classes resulted in a reverse J-shaped curve in all the undisturbed stands, while in the disturbed stands, there was a reduction in density in the higher dbh classes. The densities of seedlings and saplings were significantly higher in the undisturbed stands than the disturbed stands, although seedling density far exceeded the sapling density in all the stands. The proportion of species showing no regeneration was high in the undisturbed stand as compared to the disturbed stand. Results revealed that species richness significantly got reduced, tree population structure showed a decrease in higher girth class individuals and the regeneration status of the species was also altered due to disturbance.

Key Words: Subtropical humid forest, Species richness, Tree population, Sacred grove, Conservation.

INTRODUCTION

Most of the world's primary forests are subjected to anthropogenic disturbances to cope with the demands for various forest products (Uhl and Vieira 1989, Woods 1989). Anthropogenic disturbance alter the structure and function of primary forests. The forest disturbance by logging, grazing and farming starts or maintains a local revegetation process, which is largely dependent on the existence of the persistent species. The role of disturbance in forest dynamics has been widely studied because of its importance in the regeneration, co-existence and diversity of tree species in the forest communities (Armesto and Pickett 1985, Pickett and White 1985, Foster 1988, Rao et al. 1990, Veblen 1992, Barik et al. 1992, 1996, Molino and Sabatier 2001). Anthropogenic disturbances have been reported to regulate the regeneration dynamics, structure and floristic composition of tropical forests (Ewel et al. 1981, Horn and Hickey 1991, Hong et al.. 1995, Upadhaya et al. 2004). Connell (1978), Pimm (1984), Ehrlich and Wilson (1991), Lawton and Brown (1994), Collins et al. (1995) argued that species diversity in rain forest would be greatest where disturbances are moderate in intensity and frequency. Studies on disturbance that involves a single factor such as selective logging that is limited in extent brings relatively minor changes in structural attributes of forests (Nagaike et al. 1999, Scherer et al. 2000) and often enhances diversity (Upadhaya et al. 2004). However, frequent but low intensity disturbance (e.g., grazing and browsing, firewood extraction) may involve the combined effect of multiple factors, and may strongly affect forest structure and the ability of species to regenerate in the disturbed area (Smiet 1992, Kappelle et al. 1996). Therefore, understanding vegetation changes following the disturbance caused by different factors is essential for developing management practices involving natural regeneration (Miles 1987).

The humid subtropical forests, which accounts for 41% (9195 sq. km) of the total forest cover in the state of Meghalaya in northeast India have been exposed to various kinds of disturbances and most of these are degraded due to human activities such as shifting cultivation, timber and firewood extraction and developmental and urbanization activities. At present, these forests are found mostly in small patches, preserved and protected by the indigenous tribes in the form of 'sacred grove' due to their religious beliefs and represents the remnants of the climax vegetation of the area (Tiwari et al. 1999). These sacred groves are rich in biodiversity and harbour a large number of rare and endemic species (Haridasan and Rao 1985-1987, Tiwari et al. 1999, Pandey et al. 2005). In recent years these sacred groves are also facing serious threat due to encroachment and its conversion into village reserve forests to meet timber, fuel wood and other requirements of the village people (Khiewtam and Ramakrishnan 1989, Upadhaya 2002). The periphery of the forest is annually burnt during dry winter season to promote herbage growth in the ensuing spring season for cattle grazing (Pandey et al. 1993, Upadhaya 2002). Thus a large number of sacred forests in the state are in a degraded state. The present study was undertaken in three sacred forests located in Khasi hills of Meghalaya that represent the subtropical humid forest of the state to assess the response of woody species to human disturbances. The responses has been evaluated by studying i) species diversity, ii) density and population structure of species and iii) regeneration status of species in these forests.

STUDY SITES

The study was conducted in three sacred forests of Meghalaya viz., Swer, Nonglang and Nongkrem. Substantial portion of these sacred forests still have relatively undisturbed old- growth forest, although peripheral portions have been disturbed due to several factors, product extraction being the major cause. The latter portions of the forests represent successional stage of vegetation recovery with a few scattered old trees. In the present study, the former stands were designated as undisturbed stands and the latter as disturbed forest stands. The Swer sacred forest (latitude N $25^0$25.01' and longitude E $91^0$47.47', altitude 1925 m asl) is located on a hilly slope and covers an area of about 12 ha, of which 6 ha is protected and the rest is in a degraded state due to shifting cultivation, forest fire and grazing. The Nonglang sacred grove (latitude N $25^0$21. 8' and longitude E $91^0$27.9', altitude 1541 m asl) in the past covered an area of more than 20 ha which has been reduced to only 7 ha due to conversion of land for cultivation purpose. About half of this 7 ha area is also now in a degraded state. The Nongkrem sacred forest (latitude N $25^0$25.54' and longitude E $91^0$52.49', altitude 1781 m asl) covers an area of 7 ha. Inspite of the prohibition imposed by the traditional sacred forest governing institution on forest product extraction, the peripheral forest area of 2 ha has been due to cutting of trees for small timber, fuel wood and grazing.

METHODOLOGY

Field Methods

Stratified sampling of woody species was undertaken in the undisturbed and the disturbed stands in each sacred forest that includes (1) the adult individuals >5cm dbh at 1.3 m height and (2) the regenerating layer that includes saplings (individuals having <5cm dbh and >1m height) and seedlings (individuals having <1m height). In each sacred grove, two transects of 20m width and 250m long were run in the disturbed and undisturbed stands. Each transect was divided into fifty 10m x 10m quadrats. All the adult plants in each quadrat were tagged and measured. They were identified with the help of the regional floras (Balakrishnan 1981-1983, Haridasan and Rao 1985-1987, Kanjilal et al. 1934-1940). The Herbaria of Botanical Survey of India, Eastern Circle, Shillong and Botany Department, North-Eastern Hill University, Shillong were consulted for correct identification of plant species. The height and dbh of individuals of each species were measured in all plots and they were grouped into three height classes viz., large >15m height) that usually form the canopy, medium trees (8-15m height) constitute the subcanopy layer and small trees that do not grow above 8m height and are prevalent in the understory. There were several lianas or climbers but only individuals with 5cm dbh were enumerated. The grouping of the identified species into large tree, medium tree, small tree and lianas were done based on their growth forms and available botanical descriptions (Balakrishnan 1981-1983, Haridasan and Rao 1985-1987; Kanjilal et al. 1934-1940).

The regeneration of woody species was studied by sampling the seedling and sapling populations in 2m x2m and 5mx 5m quadrats in the center of each 10 m x10m quadrat which were used for sampling the adults. Thus a total of 50 quadrats were sampled in each stand of the three sacred forests for saplings as well as seedlings.

Frequency and Intensity of Disturbance

The anthropogenic disturbances in sacred forests have been sporadic in nature. The history of disturbance was ascertained from local elderly people through interviews. The product extraction in certain portions of the sacred forests in the past was quite high, resulting in degradation of those areas. Evidences of anthropogenic disturbances were recorded based on observations on presence / absence of woody species, product extraction, occurrence of grazing and fire. In each forest stand, the number of quadrats in which no adult individual was recorded was determined and expressed in terms of percentage of total quadrat studied. The value thus obtained indicated the intensity of disturbance in each stand.

Categorization of product extraction was made by measuring the cut stumps diameters. If the diameter of stumps is < 25cm, it was presumed that the extraction was for firewood, while stump having diameter >25cm was for timber. Qualitative observations included, presence or absence of grazing, high or low grazing intensity based on current grazing stock, and frequency of fire recorded as the number of year since last fire.

Data Analysis

The data on the individuals' 5cm dbh was analysed separately for undisturbed and disturbed stands for various phyto-sociological parameters. Density and importance value index for different woody species was computed following Misra (1968). Shannon index of diversity (Magurran 1988), and Simpson dominance index (Simpson 1949) were calculated to analyze species diversity and dominance in different stands. In order to analyze the population structure, the woody species were assigned seven dbh classes (5-15, 16-25, 26-35, 36-45, 46-55, 56-65, and >65cm).

The status of regeneration of woody species was assessed by classifying the species into a) 'good', if seedlings ≥ saplings ≥ adult; b) 'fair' if seedling ≥ saplings £ adult; c) 'poor', if a species survives in only sapling stage, but not as seedlings (though saplings may be less, more or equal to adults); d) 'none', if a species is absent in sapling and seedling stages, but present as adults; and (e) 'new', if a species has no adults, but only saplings and /or seedlings (Uma Shankar 2001).

RESULTS

Characterization of Anthropogenic Disturbance

The intensity of disturbance was higher in the disturbed stands at Swer and Nonglang, where 18 to 20% of the sampling area had no adult woody species. On the other hand, in the disturbed stand at Nongkrem the intensity was much less as all quadrats had adult woody species.

The fuel wood extraction was much more important factor for forest disturbance in all the sacred forests in comparison to timber extraction. Although small in magnitude, all the three undisturbed stands had evidences of firewood extraction, indicating that the disturbance is spreading to such area. The disturbance due to timber extraction in the undisturbed forest stand was observed only in Nonglang (Table 1). In all the disturbed stands cattle grazing was high due to the dominance of grasses in the ground layer. The frequency and occurrence of fire assessed through interview with the local people indicates revealed that fire incidences were restricted only to the disturbed stands. In Nonglang disturbed stands fire incidence occurs every 2-3 years, in Nongkrem it occurs every 3 - 5 years and in Swer it occurs once in 10-12 years (Table 1).

Species Richness

A total of 114 woody species ($\geq$ 5cm dbh) were identified in the three sacred forests. The undisturbed forest stands at Swer, Nonglang and Nongkrem had 60, 56 and 32 species, respectively. The corresponding values for the disturbed stands were reduced to 26, 24 and 24 species respectively (Table 2). As a response to disturbance, the species richness of woody species significantly reduced at all canopy levels i.e., large, medium and small tree layers as evidenced by the lesser number of species in all the disturbed stands than the undisturbed stands (Table 3). Although the species diversity of lianas was generally low in all the stands, they were completely eliminated in the disturbed stands. Of the total species in the undisturbed stands, 37, 33 and 12 species disappeared due to disturbance at Swer, Nonglang and Nongkrem respectively.
The spatial distribution pattern of species richness in each stand studied by determining species richness per $100m^2$ plots revealed that due to disturbance, the proportion of plots having less number of species increased. In all the undisturbed stands, 26-36% of the plots had <5 species, 64-72% plots had 6-10 species and only 2% plot (at Nonglang) had 11-15 species. In the disturbed stands the percentage of plots having 6-10 species decreased to about 6-14% while those having <5 species per $100m^2$ increased to 86 - 94% (Figure 1).

Shannon's diversity index computed using density of woody species varied from a minimum of 2.02 in Nongkrem disturbed stand to a maximum of 3.26 in Nonglang undisturbed stand. The diversity index was invariably low in the disturbed stands. The dominance showed a reverse trend to that of diversity, as expected (Table 2).

Density Concentration

The density of woody species ranged from 276 to 1292 individuals' ha^{-1} with a mean value of 790 + 165.3 stems ha^{-1} (Table 3). At Swer and Nonglang the density decreased from 1292 and 1000 stems ha^{-1} in the undisturbed stand to 276 and 320 stems ha^{-1} in the disturbed stand whereas, at Nongkrem it increased from 898 stems ha^{-1} in the undisturbed stand to 954 stems ha^{-1} in the disturbed stand. The distribution of woody species density per $100m^2$ plots was also affected due to disturbance. In the undisturbed stands, maximum number of plots had 6-15 individuals $100m^{-2}$. Only small proportion of plots had <5 or >15 individuals $100m^{-2}$. In the disturbed stands the percentage of plots having 6-10 individuals decreased to 10-20% while those having <5 individuals $100m^{-2}$ increased to 78%-88% (Figure 2).

In the undisturbed stand at Swer, *Symplocos javanica* was the dominant species in terms of density (302 stems ha^{-1}) followed by *Rhododendron arboreum* with 286 stems ha^{-1} (Table 4). These two species together constituted 46% of the stand density in the forest. At Nonglang, *Ficus neriifolia* had the highest number of individuals (124 stems ha^{-1}) followed by *Erythrina arborescens* (112 stems ha^{-1}) in the undisturbed stand. In Nongkrem undisturbed stand *Myrica esculenta* (256 stems ha^{-1}) and *Pinus kesiya* (162 stems ha^{-1}) contributed 47% of the total stand density. In the disturbed stands *Myrica esculenta* (58 stems ha^{-1}) and *Rhododendron arboreum* (50 stems ha^{-1}) at Swer and *Eurya acuminata* (90 stems ha^{-1}) and *Pinus kesiya* (38 stems ha^{-1}) at Nonglang and *Myrica esculenta* (374 stems ha^{-1}) and *Pinus kesiya* (214 stems ha^{-1}) at Nongkrem were the dominant and co-dominant species (Table 4).

Population Structure

Distribution of species richness was high in 5-15cm dbh class, which sharply declined in 16-25cm dbh class followed by a gradual decrease up to 65cm dbh class in all the stands. However, in the disturbed stand at Nonglang there was no species beyond 35cm dbh class (Figure 3).

The density-diameter distribution yielded reverse J-shaped curves in all the undisturbed stands. There was a sharp reduction in the number of individuals in higher dbh classes or their complete removal in the disturbed stands at Swer and Nonglang, whereas, at Nongkrem the reverse J-shaped curve was still maintained inspite of the disturbance indicating the low intensity of disturbance (Figure. 3).

The tree basal cover in the undisturbed stands of the three forest was higher than the disturbed stands (Table 2). The lower and middle girth classes contributed to greater basal cover in the undisturbed stands at Swer and Nonglang. However, in Nongkrem the higher diameter classes (>36cm dbh) contributed to maximum basal area in both the undisturbed and disturbed stands. Mature trees (26cm dbh) had less basal cover in the disturbed stands than the undisturbed stands at Swer and Nonglang, indicating the extraction pattern of trees for fuelwood in the former stands (Figure 3).

Tree Regeneration Status

The woody species seedling density was higher in the undisturbed stands than the disturbed stands indicating overall negative role of disturbance in recruitment of woody species (Table 2). The relative density of seedlings of different species revealed that *Symplocos javanica* was abundant in both disturbed and undisturbed stand at Swer, *Persea kingii* and *Myrica esculenta* were abundant in both the stands at Nongkrem, indicating little role of disturbance in recruitment of these species. *Persea gamblei* was dominant in the undisturbed stand, while *Eurya japonica* was dominant in the disturbed stand at Swer, indicating the disturbance related environmental preference of the species. Similarly, *Schefflera hypoleuca* had undisturbed environmental preference, while *Eleagnus latifolia* and *Persea odoratissima* preferred disturbed conditions at Nonglang (Table 4).

The sapling density was very low, as compared to the seedling density in all the stands (Table 2). Saplings of *Persea gamblei*, *Symplocos javanica* and *S. glomerulata* were dominant at Swer, *Schefflera hypoleuca, Symplocos javanica* and *Persea odoratissima*, were abundant at Nonglang, whereas, *Cinnamomum glanduliferum* and *Myrica esculenta* were dominant at Nongkrem undisturbed forest stand. Saplings of *Eurya japonica* at Swer and Nonglang and *Myrica esculenta* at Nongkrem were dominant species. Saplings of *Symplocos javanica Eurya acuminata, Ligustrum robustrum, Ficus neriifolia, Engelhardtia spicata and Eleagnus latifolia* were common in all the stands. Saplings of *Persea gamblei*, *Cinnamomum bejolghota* and *Helecia nilagirica* were restricted only to the undisturbed stands (Table 4).

The overall age structure of tree population as depicted by the number of seedlings, saplings and adult trees, was similar in both the disturbed and undisturbed forest stands. The seedling density was the highest, followed by a drastic reduction in sapling density and a gradual decline in the adult tree density producing an upright pyramidal structure. Although total seedling density was higher in the undisturbed stands higher proportion of species regenerated in the disturbed stands. The regeneration of ten new species was favoured by disturbance while seven new species preferred undisturbed conditions. *Schima wallichii* at Nonglang and *Elaeocarpus lancifolious* at Nongkrem were new additions in the disturbed stands. *Eleagnus latifolia*, *Leucosecptrum canum*, *Luculia pinciana*, *Lyonia ovalifolia*, *Symplocos* sp. and *Zanthoxylum acanthopodium* were new additions to the disturbed stands at Swer.

The proportion of species showing good regeneration was higher in disturbed stands than the undisturbed stands whereas, the proportion of non regenerating species was higher in the undisturbed stands (Table 5). Dominant species exhibited good to fair regeneration while less abundant species were either poorly regenerating or not regenerating.

Table 5. Number of species regenerating in undisturbed and disturbed stands at Swer, Nonglang and Nongkrem sacred forests.

Sites	Stands	Regeneration categories				
		Good	Fair	Poor	None	New
Swer	Undisturbed	18	1	6	35	1
	Disturbed	15	0	3	8	3
Nonglang	Undisturbed	23	5	4	24	1
	Disturbed	15	0	4	5	6
Nongkrem	Undisturbed	12	5	3	12	5
	Disturbed	14	5	1	4	1

DISCUSSION

Our findings demonstrate that disturbances to which these sacred forests are exposed have resulted in (1) development of a species – poor community, (2) relatively unstable population structure and (3) alteration in species composition with an increase in the species typical of open habitat (4) disappearance of many mature forest species and (5) colonization of the forest floor by new species.

The sacred forests studied are multilayered subtropical humid forest communities composed of large, medium and small sized trees distributed in three distinct strata. However, such distinct stratification was not observed in the disturbed stands that appeared more like an open and bushy forests, average height of tree being 8m. The species richness in the present study is low as compared to the earlier studies from Jaintia hills of Meghalaya (Upadhaya et al. 2004). The species richness at Nongkrem was low as compared to Swer and Nonglang due to the dominance of *Pinus kesiya* in the forest that is known to affect species diversity mainly by disrupting light to reach the ground, increases the chances of forest fire, and many species fails to germinate and establish under its canopy. Restoration of disturbed forest ecosystem depends on a number of factors such as soil seed bank, sprouting of roots and stumps of logged individuals. In the present case decrease in species diversity in the disturbed forest stand was due to repeated disturbance caused due to product extraction. Besides, the periphery of the forest is burnt during winter to promote herbage growth in the ensuing rainy season. Fire is a major barrier to natural forest regeneration because it decreases species diversity. It also causes a decline in the number of species recruiting from both the seed bank and resprouting, leading to an improvised community as documented at other tropical sites (Uhl et al. 1988). The mature forest species are most likely to be affected because their seeds germinate soon after dispersal and exhibit short dormancy period (Whitmore 1975).

The species richness of all the life form (canopy species, subcanopy, undercanopy and lianas) declined rendering the adverse effect of disturbances to all the compositional elements of the community. In additional, several endemic species of northeast India such as *Ardisia griffithii*, *Camellia cauduca*, *Carpinus vareca*, *Erythroxylon kunthianum*, *Lindera latifolia*, *Litsea laeta*, *Persea kingii*, *Prunus jenkensii*, *Schima khasiana*, and *Viburnum simonsii* and threatened category of species such as *Fraxinus floribunda*, *Hedera helix*, *Lindera latifolia*, *Mangletia insignis*, *Meliosma wallichii*, *Photonia integrifolia*, *Schima khasiana* and *Tupidanthus calyptratus* (Haridasan and Rao 1985-1987) which were present in the undisturbed stands were either poorly represented or completely absent in the disturbed stands indicating a substantial loss of taxonomically and ecologically important species. The movement by humans, grazing and fire incidence in the disturbed stands have resulted in the development of poor species community. Had these activities been absent in the disturbed stands there would have been a rapid recovery of damaged trees and release of smaller trees as observed by Quigley and Platt (2003) in seasonal forests damaged by hurricane and in subtropical broad leaved forest exposed to human disturbance due to selective felling (Upadhaya et al. 2004). Species richness was not uniformly distributed in the forest; rather the forests were mosaic of low and high diversity patches. This appears to be the result of the combined effect of non-extreme stable environmental conditions and gap phase dynamics within the forest (Whittaker 1972, Barik et al. 1992) and disturbance (Upadhaya et al. 2004). The studied forests are similar to the tropical rain forests, which have often been described as highly patchy communities (Poore 1968, Ashton 1969, Herwitz 1981) primarily due to gap-phase dynamics and disturbance.

The woody species at Swer and Nonglang showed a lower stem density in the disturbed stand. This is due to cutting of trees for use as poles and firewood extraction by villagers. At Nongkrem forest fire have lead to increase in number of species such as *Myrica esculenta*, *Cinnamomum glanduliferum*, *Pinus kesiya* and *Lithocarpus dealbatus* which are shade intolerant and are resistant to damage or to death caused by physical extremes or natural enemies that eventually fill much of the space after disturbances and concomitant increase in stem density in the disturbed stand (Connell 1978). However, the situation is rather different in case of Swer and Nonglang disturbed stand, as fire tolerance is not sufficient to assure the regeneration of many species after disturbance. Even if some species (*Myrica esculenta*, *Pinus kesiya* and Fagaceae members) tolerate fire disturbance, it becomes unfavourable for itself as it accelerates dead wood extraction by local people. In addition their removal increases the probability for the establishment of invasive grasses in recently burned sites and promotes grazing. The colonization of grasses in the disturbed sites has increased the chances of forest fire during dry season.

The regeneration in the sacred forests seems to be satisfactory at the community level as evident by the population structure of all species. However, climbers/lianas showed no sign of regeneration. Individuals remained concentrated in smaller diameter classes, while the classes of larger trees were usually absent in the disturbed stands. This is attributable to the young succession nature of the community. As succession proceeds and if mature trees are not removed, the population in disturbed stand may nearly approach those of the undisturbed stands. However, the species composition and the time taken may vary. The density of seedlings, saplings and mature tree indicated a much greater loss of individuals during the period of conversion of seedlings to saplings which is a more vulnerable stage in the life cycle or life history of the species as compared to the period during which the saplings developed into the adult trees. However, a detailed investigation of the seedlings survivorship and mortality over a period of time is needed to arrive at such conclusions. High mortality and low growth rate are typical for juvenile of rainforest trees due to low understory light level, exposure to physical and biotic disturbances and the short-term water deficits (Kobe 1999, Davies et al. 1999).

The perpetuation of a species depends on the presence of adequate number of individuals of different growth phases or developmental phases of that species. These conclusions are subjective to a certain extent, since the relative number of adults and juveniles does not seem to be a consistent trait across species. While some species could succeed with a relatively small stock of juveniles, other depends on a large stocking of juveniles to compensate for mortality (Swaine and Hall

1988, Uma Shankar 2001). Nonetheless, inadequate regeneration of the constituent species is a general phenomenon in Indian forests because of grazing, fire, timber and fuelwood cutting and cultivation. The reduction in seedling and sapling density in the unprotected stand of the sacred forests could be ascribed to the impact of movement by human and cattle and forest fire. The presence of seed bearing parent trees is another important factor for obtaining higher seedling density in the forest. The density of seed bearing parent plants was more in the undisturbed forest stands resulting in more recruitment of seedlings besides relatively less disturbance events in these stands allow seeds to germinate, resulting in overall higher seedling density in the undisturbed stands. On the other hand, in the disturbed stands less number of seed bearing trees and concurrent disturbances reduced the woody species seedling density. Similar observations were made by Chapman and Chapman (1997), who had also reported lower juvenile density in heavily logged tropical forest at Kibale National Park, Uganda. Very few species maintained their populations in the disturbed stands. This indicates that many species fail to recolonize such stands and may face local extinction (Niemela et al. 1992). The density which is fairly distributed among different species group in the undisturbed stand is lopsided in favour of two-three species such as *Rhododendron arboreum* and *Myrica esculenta* at Swer, *Pinus kesiya* and *Eurya acuminata* at Nonglang and *Myrica esculenta* and *Pinus kesiya* at Nongkrem disturbed stand. These species are light demanding and performs well in large gaps and disturbed areas and thus responsible for greater abundance in the disturbed stands.

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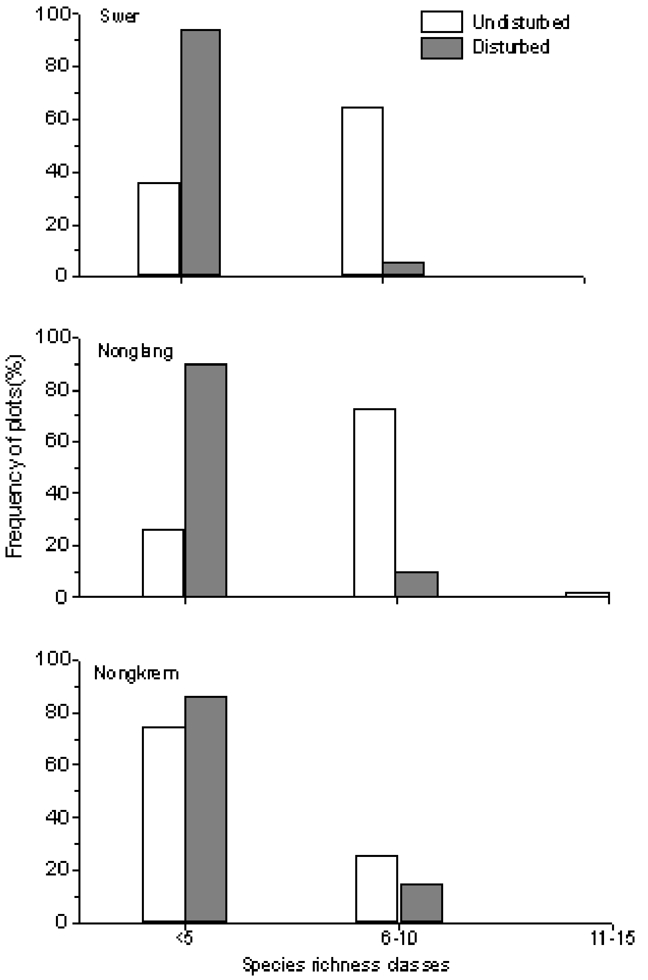

Figure 1. Species richness per 100m^2 in the undisturbed and disturbed stands at Swer, Nonglang and Nongkrem sacred groves

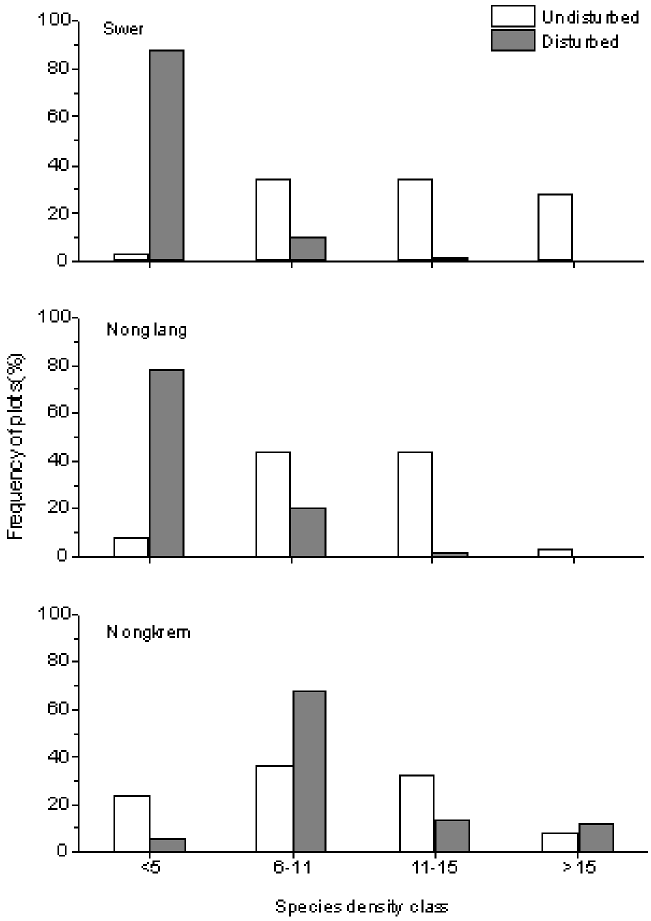

Figure 2. Number of individuals per 100m^2 in the undisturbed and disturbed stands at Swer, Nonglang and Nongkrem sacred groves

Table 1. Anthropogenic disturbances recorded in the sacred forest at Swer, Nonglang and Nongkrem

Source of disturbance	Swer		Nonglang		Nongkrem	
	Undisturbed	Disturbed	Undisturbed	Disturbed	Undisturbed	Disturbed
Extent of disturbance						
Percent plots without trees	0	18	0	20	0	0
Extraction						
Firewood (% of total density)	1	12	2	6	1	3
Timber extraction (% of total density)	0	1	2	1	0	1
Live stock grazing						
Browsing trace	Absent	Present	Absent	Present	Present	Present
Live stock density	None	High	None	High	Low	Low
Frequency of fire (years)	None	>10	None	Every 2-3	None	3-5

Table 2. Consolidated summary of plant diversity and community characteristics in the undisturbed and disturbed stands at Swer, Nonglang and Nongkrem sacred forests

Variables	Swer		Nonglang		Nongkrem	
	Undisturbed	Disturbed	Undisturbed	Disturbed	Undisturbed	Disturbed
Area sampled (ha)	0.5	0.5	0.5	0.5	0.5	0.5
Woody species richness	60	26	56	24	32	24
Number of genera	45	22	44	19	20	28
Stand density (ha^{-1})	1292	276	1000	320	898	954
Stand basal area (m^2 ha^{-1})	47	10.44	26.76	3.13	62.42	58.25
Shannon's diversity index	2.82	2.66	3.26	2.52	2.40	2.02
Simpson dominance index	0.120	0.105	0.061	0.126	0.147	0.190
Sapling species richness	25	21	30	25	25	18
Saplings density (ha^{-1})	188000	169200	150800	74800	114800	103200
Seedling species richness	19	16	28	17	17	20
Seedlings density ($100m^2$)	21150	10750	9475	3975	5375	5075

Table 3. Distribution of woody species in different growth forms at Swer, Nonglang and Nongkrem sacred forests

Categories	Swer		Nonglang		Nongkrem	
	Undisturbed	Disturbed	Undisturbed	Disturbed	Undisturbed	Disturbed
Large trees (>15 m height)	19	7	18	7	11	9
Medium tree (>8<15m height)	16	7	18	10	6	6
Small tree (<8m height)	20	12	18	7	13	8
Lianas/Climbers	5	0	2	0	2	1
Total	60	26	56	24	32	24

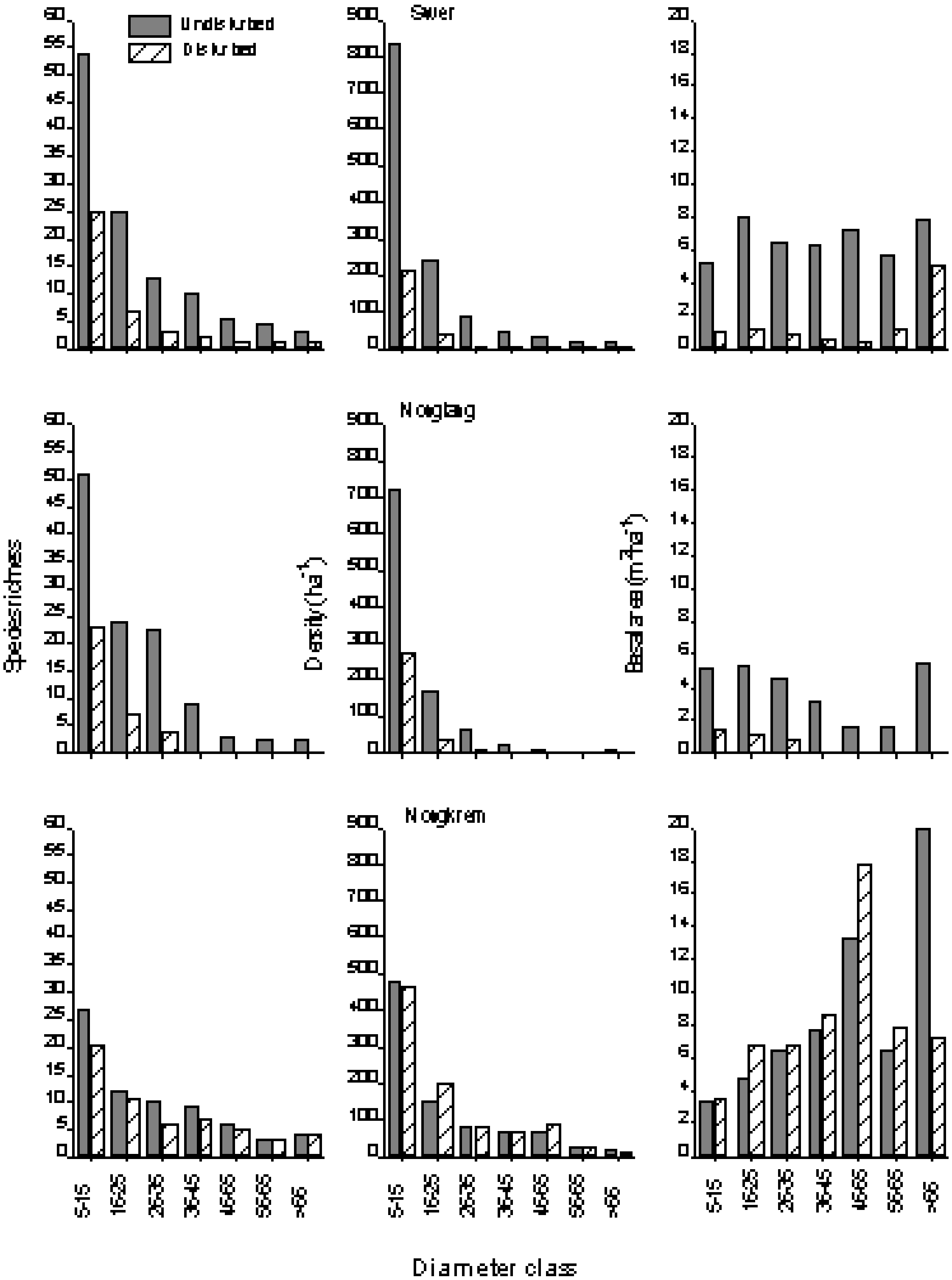

Figure 3. Distribution of species richness, density and basal area in different diameter classes in undisturbed and disturbed stands at Swer, Nonglang and Nongkrem sacred groves

Table 4. Density of seedlings (S, per 100m^2), saplings (Sa) and adult trees (Ad) (per ha^{-1}) of woody species (> 5cm dbh) in the undisturbed and disturbed stands at Swer, Nonglang and Nongkrem sacred forests.

Name of species	Family	Swer						Nonglang						Nongkrem					
		Undisturbed			Disturbed			Undisturbed			Disturbed			Undisturbed			Disturbed		
		S	Sa	Ad	S	Sa	Ad	S	Sa	Ad	Se	Sa	Ad	Se	Sa	Ad	Se	Sa	Ad
Canopy layer species																			
Castanopsis purpurella	Fagaceae	-	-	-	-	-	-	50	-	14	-	-	-	-	-	-	-	-	-
Cinnamomum bejolghota	Lauraceae	25	1600	4	-	-	-	25	3600	14	-	-	-	-	-	-	-	-	-
Cinnamomum glanduliferum	Lauraceae	-	-		-	-	-	-	-	-	-	-	525	21200	28	275	10400	84	
Elaeocarpus lancifolious	Elaeocarpaceae	575	12400	24	-	-	-	-	-	-	-	-	-	75	3600	-	25	-	6
Engelhardtia spicata	Juglandaceae	75	2400	10	-	1200	2	175	2800	8	75	1200	6	50	800	8	50	800	8
Lithocarpus dealbatus	Fagaceae	-	-		-	-		-	-	-	-	-		450	13600	128	100	4000	200
Magnolia sp.	Magnoliaceae	-	800	38	-	-		-	-		-	-	-	-	-	-	-	-	-
Myrica esculenta	Myricaceae	-	-	8	450	1600	58	-	-	6	75	800	4	1300	36800	256	1525	37600	274
Neolitsea cassia	Lauraceae	1150	18000	44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Persea gamblei	Lauraceae	10000	41200	84	-	-	-	900	6400	12	-	-	-	-	-	-	-	-	-
Persea kingii	Lauraceae	-	-		-	-		-	-		-	-	-	1375	8400	48	1025	11600	26
Persea odoratissima	Lauraceae	900	10400	54	350	3600	4	625	12000	16	475	400	4	-	-	-	-	-	-
Pinus kesiya	Pinaceae	-	-	2	-	-	6	25	-	28	-	400	38	225	-	162	-	-	214
Rhodododendron arboreum	Ericaceae	-	400	286	500	8400	50	-	10800	-	-	-	-	-	-	-	-	-	-
Rhus acuminata	Meliaceae	-	-	-	-	-	-	-	-	34	25	1200	8	50	800	34	50	1600	20
Others		475	6400	32	0	1200	4	375	9600	78	125	2400	4	25	400	16	50	2800	2
Subcanopy layer species																			
Erythrina arborescens	Fabaceae	-	-	-	-	-	-	150	3200	112	-	-	2	-	-	-	-	-	-
Ficus nerifolia	Moraceae	-	2400	18	50	2400	4	625	12000	124	150	5600	24	-	400	10	50	1600	6
Glochidion sp.	Euphorbiaceae	150	800	16	-	-	-	375	7600	10	75	2800	4	-	-	-	-	-	-
Ligustrum robustrum	Oleaceae	50	400	16	175	3200	24	200	4000	8	125	2000	6	-	-	-	-	-	-
Macropanax dispermus	Araliaceae	-	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-	-	-
Photinia integrifolia	Rosaceae	75	1200	38	600	1200	10		800	4			-		800	4		400	2
Pyrus pashia	Rosaceae	-	-	2	-	-	8	-	-	-	-	-	-	25	-	4	50	-	2
Saurauia macrotricha	Saurauiaceae	-	-	-	-	-	-	100	5200	100	-	800	20	-	-	-	-	-	-
Schefflera hypoleuca	Araliaceae	275	3200	20	-	-	4	1300	16400	30	350	2400	6	-	-	-	-	-	-

Table 4. (Continued)

Name of species	Family	Swer						Nonglang						Nongkrem					
		Undisturbed			Disturbed			Undisturbed			Disturbed			Undisturbed			Disturbed		
		S	Sa	Ad	S	Sa	Ad	S	Sa	Ad	Se	Sa	Ad	Se	Sa	Ad	Se	Sa	Ad
Symplocos javanica	Symplocaceae	3900	40400	302	1000	1200	4	1750	17200	46	275	2000	20	750	10800	58	875	9200	46
Viburnum simonsii	Caprifoliaceae	-	800	2	75	1200	14	-	-	-	-	-	-	-	-	-	-	-	-
Others		975	14000	68	0	0	0	850	11600	50	150	1600	12	25	1200	4	0	0	4
Undercanopy / treelet layer																			
Elaeagnus latifolia	Elaeagnaceae	-	800	-	125	400	2	850	-	64	725	7200	24	25	2000	24	225	3600	26
Eurya acuminata	Theaceae	25	2400	14		10000	10	475	8000	100	400	15600	90	-	400	8	75	1600	4
Eurya japonica	Theaceae	-	-	10	3600	68000	24	350	6800	38	525	20400	32	-	-	2	-	-	2
Leucosceptrum canum	Lamiaceae	-	-	-	800	9600	8	-	-	-		2000	-	-	-	-	-	-	-
Lyonia ovalifolia	Ericaceae	-	-	2	775	11200	16	-	-	-	-	400	-	-	-	-	-	-	-
Mussanda roxburghii	Rubiaceae	-	-	-	-	-	-	150	6800	20	-	1200	2	-	-	-	-	-	-
Phlogacanthus tubiflorus	Acathaceae	-	-	-	-	-		-	-	-	-	-	-	-	-	36	-	-	4
Polygala arillata	Polygalaceae	-	-	-	-	-		-	-	-	-	-	-	100	4800	14	250	6400	8
Psychotria symplicifolia	Rubiaceae	-	-	30	-	-	-	150	400	2	-	400	-	-	-	-	-	-	-
Symplocos crategoides	Symplocaceae	-	-	2	75	800	-	275	2400	14	50	1600	4	200	800	14	275	800	8
Symplocos glomerulata	Symplocaceae	2250	24800	80	75	1200	2	-	-	-	-	-	-	-	-	-	-	-	-
Symplocos spicata	Symplocaceae	250	2400	10	-	400	-	-	-	-	-	-	-	75	4000	2	25	6800	2
Others		0	800	40	2100	42400	22	200	3200	50	375	2400	10	100	4000	22	150	4000	4
Lianas		0	0	36	0	0	0	0	0	4	0	0	0	0	0	6	0	0	2
Total		21150	188000	1292	10750	169200	276	9975	150800	1000	3975	74800	320	5375	114800	898	5075	103200	954

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