Effect of gap size on the species composition in humid tropical forests of Uttara Kannada district, Western Ghats, South India.

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Summary.

Species composition in twenty seven regenerating gaps, of which 16 were small (<200 m^2) and 11 were large gaps (>200 m^2), was studied in humid tropical forests in Sharavati and Aghanashini river valleys of Uttara Kannada district, Western Ghats, south India. Comparison of number of species, number of individuals and similarity index (SI) between regenerating small and large gaps showed significant difference. This indicates that microenvironment and heterogeneity of the gap has greater influence in establishment, survival and abundance of species. Lower number of species in small gaps could be attributed to hospitable environment for the shade-tolerant species. Heterogeneity in the large gap habitat and transportation of seeds of different species from other seed sources favoured many species to regenerate in large gaps. Changes in number of species in regenerating small and large gaps affected the composition, decreased similarity, leading to significant difference in the similarity index between small and large gaps. Closer similarity of large gaps with adjacent forests suggests the advance regeneration and least disturbance during gap formation. Dominance of tree species among different life forms in gaps and adjacent forests indicates their capacity to remain suppressed for long period as seedlings and regenerate when the conditions are favourable. Less number of species and lower population density of herbs in gaps is suggestive of the canopy opening over a period of time.

Key words: gap size, species composition, life form, humid forests,

Western Ghats, India.

Introduction

Tropical humid forests are mosaic patches of different age, structures and communities, with closed canopies and rich species diversity. Mosaic nature of these forests has been attributed to regeneration of gaps resulting in heterogeneity in the species composition. Gap-phase recovery has been considered to be playing key role in maintaining species diversity and mosaic nature of the tropical humid forests. Heterogeneity in the gap habitat favours the co-existence of many species. Therefore, gaps are considered as the sites of forest regeneration and silvigenesis. Hence understanding of gap-phase recovery in different ecosystems and regions is helpful to evolve strategies for improving the vegetation management, enhancing the regeneration of timber and other useful species, promotion of diversity, increase production of biomass and carbon sequestration.

Natural calamities and anthropogenic disturbances disrupt the forest canopy forming openings varying in size, geometry and age. Forest gaps alter the microenvironment in the opened forest area by influencing availability and intensity of light, increase air and soil temperature, affect the relative humidity of soil and air, and availability of nutrients, which are known as the main regeneration controlling factors. These factors are important in deciding species composition and their assemblage in regenerating gap. Considering the area, canopy openings are broadly categorized into small and large gaps. Studies have reported that small gaps are occupied either by species present in the adjacent natural forest (Bazzaz 1996) or by the growth of the branches of trees bordering the gaps (Hibbs 1982, Guldin & Lorimer 1985), and reflect the original stand structure and composition. But the large gaps are occupied by other species apart from those in the neighbouring forest, resulting in a stand /patch of different structure and composition.

Information available on gap-phase recovery deal with gap size frequency in forest area (Brokaw 1985a, Whitmore *et al* 1993, Dalling *et al* 1998), extent of gap area in proportion to total forest area (Sanford *et al* 1986, Barton *et al* 1989, Yavitt *et al* 1995, Brokaw 1996, Hubbell *et al* 1999), ecological species categories, their composition and dominance (Brokaw 1985, 1987, Lawton & Putz 1988, Pompa *et al* 1988), seasonal frequency of gap formation and floristic change (Brokaw 1982 b, Hartshorn 1980, Whitmore 1982), biomass accumulation and growth rate (Denslow 1980), and nutrient dynamics (Uhl *et al* 1988). Most of the studies on gap-phase regeneration are from Barro Colorado Islands (BCI) Panama, La Selva, and Far Eastern region including few from India (Chandrashekara & Ramakrishnan, 1994 a, b, Barik *et al* 1992).

Western Ghats in southern India support the humid tropical forest and the gaps of different size are formed as a result of natural events (death /fall of trees/ branches, up-rooting, snapping of trees etc) and also due to deliberate removal of trees by humans. A few studies deal with gap succession, dynamics, productivity and floristic composition (Chandrashekara & Ramakrishnan 1993; Chandrashekara & Ramakrishnan 1994 a, b), but studies addressing the effect of gap size on the species composition in regenerating small and large gaps and to suggest management strategies are lacking. The objectives of the present study are to assess – the species composition in gaps and adjacent natural forests, the relationship between gap size and species richness and diversity, impact of gap size on similarity of regenerating vegetation with the neighbouring forests.

Methodology:

Study area:

This study was undertaken in the humid/ wet tropical forests of Uttara Kannada district (lat., 13° 55 'to 15° 31' N and long., 74° 9 to 75° 10' E), Western Ghats, south India. Comprising an area of 10,200 Km^2, the district is hilly terrain with gentle slopes and broad valleys with an altitude ranging from the sea coast to a little over 1000 m. It is one of the most forested tracts of southern India. Topographically the district may be divided into 3 zones: the flat and narrow coast, abruptly rising ridge and the flatter elevated eastern zone that joins with the Deccan Plateau.

The district receives rainfall from south-west monsoon and it is largely restricted to the months from June to September. Annual rainfall in the district ranges from 350 cm. near the coast to more than 500 cm. at some places along the ridge of the hills. Eastern side of the district receives about 120 cm of rainfall annually.

Study location

Total number of forest gaps selected was 27 (16 small gaps, <200 m^2 and 11 are large gaps, >200m^2) located in wet evergreen forests facing the western slope in the valleys of Sharavati and Aghanashini rivers in the district.

Brief description of vegetation

The Natural vegetation of the district is evergreen / semi-evergreen type along slopes and towards east of the ridge it is moist deciduous type. Puri (1960) has classified the forest facing the western slope as tropical wet evergreen forest type. Champion & Seth (1968) have classified the forest on the western slope as tropical evergreen type. Considering the abundance of species Pascal (1982, 1986) classified the vegetation of the lower elevation of the district as *Persea macarantha - Diospyros spp - Holigarna spp* type. According to him the summits of plateau are covered with *Memecylon umbellatum - Syzygium cuminii - Actinodaphne angustifolia* type of forests. In evergreen forests *Hopea wightiana, Bischofia javanica, Holigarna arnottiana, Flacourtia montana, Ixora brachiata* etc., species dominate the canopy, the undergrowth consists of *Strobilanthus sps, Calamus sps, Uvaria sps* etc,.

Methods

For the present study openings in the canopy through which the sky is visible has been defined as the gap. Forest gaps were located by walking in the forest. Field notes were recorded relating to the cause of formation of gap (i.e. anthropogenic or natural) and nature of the slope. Site location details (latitude, longitude, slope and altitude) were observed using GPS and recorded in the spot.

Extent of the gap is marked by placing a rope along the perimeter of the canopy opening. Four corners in all directions is fixed to cover the maximum gap area and to make this area a tetrangle, henceforth it is called as **total gap area**. Length of all sides of the total gap area is recorded and used to calculate the gap area Based on the total area, they are grouped as small gaps if <200m^2 or large gaps if the area covered is >200m^2

Mid points of opposite sides of the gap are joined and crossing of the lines is fixed as the centre of the gap. A transect of 2m width from the centre of the gap is laid in all the directions till it touched mid point of the gap border (henceforth it is referred as **measured gap area**). Each transect i.e., measured gap area, was divided into 2m X 2m sub-quadrats to record the species and the number of individuals of different life forms which are <30 cm girth at breast height (=132 cm). From the mid point of the gap border a transect of the same length and width was extended inside the natural forest (henceforth referred as **measured forest area**) and enumeration of different life forms was carried out in 2m x 2 m sub -quadrates.

Individuals were identified by their species names, but doubtful entities were noted as unknown I, II, III, etc. Total number of species observed in measured gap area and in natural forest was calculated by pooling the enumeration data of four transects in each category. Number of species common to both these categories was also calculated and the Similarity Index (**SI**) was calculated as - **2C/ A+ B**, where, **C**= No. of Species common to gap area and natural forest, **A** = No. of species in natural forest , **B** = No. of species in gap area. % Similarity between natural forest and gap area was obtained by multiplying '**SI**' value with 100.Species diversity index ($\bar{H}$) was calculated following - Σ Pi log Pi, where Pi is the proportion of the i th species. Index of species richness (**d**) was calculated as **s/n**, where **s** = number of species and **n** = number of individuals. Species density was calculated as - No.of species/measured area.

Results:

Details of sampling locations, size of the gaps, causes for formation of gaps and other characteristics are given in Table 1. Total area of the measured small gaps ranged from 49.68 to 186.66 m^2 with an average area of 113.16 m^2 and measured large gaps ranged from 207.00 to 2531.25m^2 with an average area of 620.02 m^2. Floristic details of the study sites are given in Table 2. Number of species in the measured area of the small gaps ranged from 33 to 63, in measured large gaps it ranged from 50 to 80. In measured small forests it ranged from 31 to 61 and in measured large forests it ranged from 47 to 83.Average number of species was 45 in measured small gaps and forests, and it was 60 and 59 in measured large gaps and forests respectively (Table 2) Comparison of number of species in measured small and large gaps showed significant difference ($t_{0.01(2, 25)} = 4.39$, Table 3). Similarly, comparison of number of species between measured small and large forests also showed significant difference ($t_{0.01(2, 25)} = 3.86$, Table 3). Average number of individuals was more in measured small gaps than in forests, but it was more or less same in measured large gaps and forests (Table 2). Comparison of number of individuals between measured small and large gaps showed significant difference ($t_{0.01(2, 25)} = 3.75$) and also between measured small and large forests ($t_{0.01(2, 25)} = 4.19$, Table 3). Similarity index ranged from 56.25 to 81.16 % with an average of 69.71 % in measured small gaps and forests, while in measured large gaps and forests it ranged from 65.52 to 83.44 % with an average of 75.3 % (Table 2). Comparison of similarity index values between measured small and large gaps and also between measured small and large forests showed significant difference ($t_{0.05(2, 25)} = 2.49$, Table 3). Index of species richness **(d)** in measured small gaps ranged from 0.04 to 0.19 with an average of 0.11 and in measured small forests it ranged from 0.03 to 0.23, the average value being 0.13 (Table 2). In measured large gaps it ranged from 0.04 to 0.09 and in measured large forests it ranged from 0.05 to 0.12, the average is 0.07 for both (Table 2). Comparison of index of species richness between measured small gap and forest showed significant difference ($2.91_{(2, 25)}$, $p < 0.05$) and comparison between measured large gaps and forests also showed significant difference ($3.64_{(2, 25)}$, $p < 0.01$, Table 3). Average species density in measured small gap was 1.05 and in measured small forest it was 1.06, in measured large gap and forests 0.71 and 0.69 respectively (Table 2). Comparison of species density between measured small gaps and forests showed significant difference ($3.53_{(2, 25)}$, $p < 0.01$), such comparison between measured large gaps and forests also showed significant difference $4.280_{(2, 25)}$, $p < 0.01$, Table 3).

Number of species showed positive correlation with: measured small gap area ($\mathbf{r}_{0.01\,(2, 14)} = \mathbf{0.63}$), measured small forest area ($\mathbf{r}_{0.01\,(2, 14)} = \mathbf{0.73}$), measured large gap area ($\mathbf{r}_{0.01\,(2, 9)} = \mathbf{0.88}$) and large forest area ($\mathbf{r}_{0.01\,(2, 9)} = \mathbf{0.91}$, Table 4). Positive correlation was observed between number of individuals and measured small forest area ($\mathbf{r}_{0.01(2, 9)} = \mathbf{0.97}$, Table 4) and between number of individuals and measured large forest area ($\mathbf{r}_{0.01\,(2, 9)} = \mathbf{0.85}$, Table 4). Species diversity index showed positive correlation with measured small forest area ($\mathbf{r}_{0.05\,(2, 14)} = \mathbf{0.56}$, Table 4) and also with measured large forest area ($\mathbf{r}_{0.01\,(2, 9)} = \mathbf{0.72}$, Table 4).

Among different life forms, on an average, tree species dominated in measured small and large gaps and forest areas (Table 5 and Fig .1), but the average number of individuals of shrubs in measured large gap area was slightly more than the tree individuals (Table 6, **Fig 2).**

Discussion:

Number of species in measured small forests and gaps is more or less same, but measured large gaps have slightly more number of species than measured large forests (Table 2). Disruption of forest canopy leads to the formation of gaps varying in size and shape, which triggers the germination of seeds present in the soil and release seedlings already established in the understorey (Denslow 1987). The environmental conditions in gaps differ from the closed forest canopy. In large gaps sunlight reaches the ground level, and temperature and humidity regimes match more or less with the open clearings (Richards 1996), but in small gaps the microclimate is similar to that in the adjacent understorey (Whitmore 1990). Gaps offer specialized regeneration conditions due to prevailing spatial and microenvironmental heterogeneity, which create a number of potential regeneration niches (Barik *et al* 1992). With the formation of gap, colonization of different species sets in through seed rain, germination of seeds in soil and establishment of advance regeneration. Though many individuals of different species germinate in gaps, over the years, reduction in number of individuals and species occurs by competitive self-thinning. Species occupying these gaps have been broadly categorized as shade-tolerant and – intolerant (Brokaw 1985 b, Denslow 1980, Hibbs 1982, Runkle 1985, Whitmore 1989) In small gaps environment is closer to natural forest and it is more favourable for shade- tolerant species. Availability of light is a critical factor and it is controlled by the height of the canopy trees. Arrival of propagules from different sources is impeded due to greater height of canopy trees present in the surrounding vegetation (Swaine & Hall 1983, Denslow & Gomez 1990, Martinez-Ramos & Solo - Castro 1993, Abe *et al* 1995). So, only the shade – tolerant species capable of surviving and establishing under poor illumination can come up in small gaps. This could be attributed for the observed few species and individuals in measured small gaps and forests.

Environmental conditions in large gaps are different from the natural forest; therefore, individuals of different species belonging to both shade – tolerant and - intolerant groups germinate (Brokaw and Scheiner 1989). Seeds of the neighbouring forest establish in the gap area and gap also receives seeds from other areas Due to two seed sources both shade tolerant and intolerant species establish in large gaps. In large gaps greater habitat heterogeneity favour multi-species co-existence (Grubb 1977). This could be the reason for the observed more number of species and individuals in measured large gaps than in small gaps. Habitat heterogeneity increases with the increase in area (Orians 1983) and species specialized to survive under such conditions occupy and establish. Probably this could be the reason for the observed positive correlation between number of species with measured small and large gaps as well as the forest areas (Table 4).

Denslow (1980) and Brokaw (1985 a) have stressed importance of gap size in determining the floristic composition in regenerating gaps. According to Garwood (1989) in small gaps the regeneration is through intensive growth of advance regeneration (i.e. seedlings and saplings present before the formation of gap), where as in large gaps the regeneration is through seed rain or due to seed bank of pioneer species. Though shade-tolerant and non-tolerant species occupy small gaps only the former group of species establish in shade. Therefore, the floristic composition in regenerating small gaps is unlikely to be different from the surrounding natural forest (Anonymous 1978) This could be the reason for the observed closer similarity (average **SI** =69.71%) between small gaps and forests (Table 2). But in measured large gaps and forests, the average similarity index value was very high (**SI** =75.30%), which is contrary to the expected trends. Studies have reported that disturbances enhance diversity by reducing dominance of one or several species and release resources for less competitive species to grow and reproduce (Connell 1978, 1980, 1989) or else, increase environmental heterogeneity by generating a basis for a higher specialization and resource partitioning (Chesson 1986, Chesson & Warner 1981, Hubbell 1979, Tilman 1982). According to Runkle (1985) severity of disturbance determines the path of regeneration in gaps. According to him mild disturbance event/s favour the suppressed sapling strategy, whereas, severe disturbance may eliminate suppressed saplings and hence well represented species in the seed bank would be favoured. So the observed closer similarity between measured large gap and forest indicates that large gaps are formed due to mild events and the suppressed sapling strategy was favoured. Since the disturbance was mild advance regeneration took place leading to closer similarity between measured large gap and forest.

In the present study comparison of index of species diversity ($\bar{\mathbf{H}}$) between measured small and large gaps, and measured small and large forests showed no significant difference(Table 3). This indicates that there is no dominance of one species in sharing the individuals Species diversity index showed positive correlation with measured small and large forest areas indicating increase of heterogeneity of microhabitats favouring accommodation of more number of species.

Comparison of index of species richness (**s/n**) between small and large gaps showed significant difference (Table 3). This could be attributed to sharing of more individuals by few species as in measured small gaps. Seedling density indicates the resilience potential of forests against disturbance and higher sampled species is the indicator of greater species richness in gaps and forests. In the present study density of individuals is quite high in measured gaps and forests suggesting greater tolerance to disturbance. But when the species density is considered measured large gaps comprised more species than the measured forests and more species in measured small forests than in small gaps (Table 2) This suggests that there is more recruitment of species in large gaps because of hospitable environment, while less species density in small gap indicates that the environment is conducive only for those capable of surviving under such condition.

Barik *et al* (1992) and Chandrashekara & Ramakrishnan (1994 a, b) have reported dominance of tree species among different life forms in undisturbed humid tropical forests. Adequate seedling density of tree species on the forest floor has been reported from many humid forests (Richards 1996, Uhl *et al*1988). In the present study also, among different life forms, on an average, tree species dominated in measured small and large gaps and forests (Table 5, **Fig.1**), but the average number of individuals of shrubs in measured large gap area was slightly more than the tree individuals (Table 6, **Fig. 2)**. According to Denslow (1980), Hartshron (1978), Lang & Knight (1983) and Whitmore (1978), canopy openings are critical for the regeneration of canopy tree species. In the present study, it was observed that tree species were more in measured gaps as well as in forests, indicating their presence as suppressed seedlings or as advance regeneration. Minimum number of species and individuals in herb category were observed in gaps and forests Though the gap environment is favourable initially for the establishment of annual and perennial herb species, over a period of time, availability of light is impeded due to growth of other life forms, mainly the trees and shrubs. Competition for nutrients and moisture also enhances the elimination of herbs resulting in the reduction in number of species and population density (Chandrashekara & Ramakrishnan, 1994 a, b). So fewer herb species and lesser density in gaps indicate that canopy opening has occurred over a period of time.

Conclusion

Micro environmental conditions in small gaps have greater influence in determining the floristic composition. Greater species richness in large gaps could be attributed to arrival of seeds from different sources and also on account of habitat heterogeneity Similarity of species between large gaps and forests could be due to least disturbance to the well-developed advance regeneration. Dominance of tree species among different life forms is attributable for their capacity to remain suppressed for a long period and for taking the advantage of formation of gap for growth. Presence of lower number of species and individuals of herb species in gaps suggests that they were formed over a period of time.

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Legend to Tables

Table :1. Details of sampling locations and other characteristics

Table : 2. Floristic details of gaps and forests.

Table :3. Comparison of number of species, number of individuals, species diversity index , Similarity index values , index of species richness and species density in measured gap and forest area.

Table: 4. Details of correlation co-efficient ' r 'values for number of species, individuals and species diversity in gap and forest area.

Table : 5. Number of species under different life form category in measured small and large gaps and forests

A. Number of species under a life form category in small measured sites.

B. Number of species under a life form category in large measured sites.

Table : 6. Number of individuals and their percentage under different life forms in measured small and large gaps and forest areas.

A. Number of individuals and their percentage under different life forms in small measured area.

B. Number of individuals and their percentage under different life forms in large measured area

Legend to Figures

Fig.1. Percent of species in different life forms in small and large measured gaps and forests.

Fig.2. Percentage of individuals indifferent life forms in small and large measured gaps and forests.

Table 1. Details of sampling locations and other characteristics

Sl. No.	Altitude in feet	Site	Total area m^2	Measured area m^2	Cause of formation of gap
			Small gaps		
1	1947	Gijaguni-I	49.68	27.00	Natural death of tree.
2	2060	Kalavan-II	63.90	33.80	Natural death of trees.
3	1815	Gijaguni-II	49.68	34.00	Natural death of tree.
4	1785	Katlekan(MG)-IV	83.42	34.20	Falling of tree.
5	1933	Katlekan-II	61.64	34.20	Natural death of tree.
6	1909	Katlekan-I	77.70	36.40	Uprooting of trees.
7	1781	Bilgodu-III	80.64	36.40	Naturally dead and fallen tree.
8	1547	Kodigadde-IV	137.78	44.60	Dead and fallen tree.
9	2235	Kalavan-III	109.80	46.00	Naturally dead and fallen tree.
10	1775	Katlekan(MG)-III	129.36	46.00	Breaking of the tree.
11	1935	Bilgodu-I	125.00	46.80	Naturally dead and fallen tree.
12	2005	Kalavan-I	167.03	50.80	Natural death of trees.
13	1924	Hejani-II	155.94	51.80	Naturally dead and fallen tree.
14	1944	Katlekan(MG)-II	157.52	54.50	Death and falling of two trees.
15	1914	Hejani-I	174.90	56.40	Uprooting of trees.
16	1817	Katlekan(MG)-VI	186.66	53.60	Falling of two dead trees.
		Average	**113.16**	**42. 91**	
		Maximum	**186. 66**	**56. 40**	
		Minimum	**49.68**	**27. 00**	
			Large gaps		
1	1784	Bilgodu-II	207.00	66.20	Naturally dead and fallen tree.
2	1955	Gijaguni-III	215.00	65.50	Gap formed due to standing dead trees.
3	1817	Katlekan(MG)-V	224.48	59.40	Breaking of tree.
4	1470	Kodigadde-V	332.77	70.20	Death of four trees, extracted by forest dept.
5	1695	Basavanabailu	259.42	58.80	Multiple tree falling
6	1782	Kodigadde-I	432.60	66.00	Naturally dead trees, extracted by forest dept.
7	1731	Katlekan(MG)-I	361.79	77.50	Dead and fallen tree.
8	1670	Kodigadde-II	631.80	72.00	Falling of tree
9	1547	Kodigadde-III	226.56	55.00	Dead and fallen tree.
10	1634	Mastimane	1397.50	144.00	Natural death of tree.
11	1552	Katlekan(MG)-VII	2531.25	198.00	Multiple tree falling.
		Average	**620.02**	**84.78**	
		Maximum	**2531**	**198**	
		Minimum	**207**	**55**	

Table 2. Floristic details of gaps and forests

Details of small gaps and forests

Sl No	Name of the sampling site	No of individuals in measured area		No of individuals / ha		Seedling density (No. of individuals / m^2)		No of species in measured area		Species diversity (H) in measured		Similarity index (SI ,%) between gap and forest	Index of species richness (s/n , s =No. of species, n = No. of individuals in measured area)		Species density (No. of species / Measured area)	
		Gap	Forest	Gap	Forest	Gap	Forest	Gap	Forest	Gap	Forest		Gap	Forest	Gap	Forest
1	Gijaguni-I	220	229	81481	84815	8	8	34	35	2.81	2.50	81.16	0.15	0.15	1.26	1.30
2	Kalavan-II	507	470	150000	139053	15	14	50	44	2.92	2.84	68.09	0.10	0.09	1.48	1.30
3	Gijaguni-II	604	1114	177647	327647	18	33	35	36	1.70	1.10	67.61	0.06	0.03	1.03	1.06
4	Katlekan(MG)-IV	239	219	69883	64035	7	6	45	45	3.30	3.33	71.11	0.19	0.21	1.32	1.32
5	Katlekan-II	223	137	65205	40058	7	4	33	31	2.86	2.93	56.25	0.15	0.23	0.96	0.91
6	Katlekan-I	233	182	64011	50000	6	5	43	36	3.34	3.00	60.76	0.18	0.20	1.18	0.99
7	Bilgodu-III	868	427	238462	117308	24	12	37	40	1.11	2.77	67.53	0.04	0.09	1.02	1.10
8	Kodigadde-IV	382	382	85650	85650	9	9	39	46	2.93	3.05	68.24	0.10	0.12	0.87	1.03
9	Kalavan-III	364	396	79130	86087	8	9	43	43	2.87	2.93	69.77	0.12	0.11	0.93	0.93
10	Katlekan(MG)-III	533	461	115870	100217	12	10	48	52	3.09	3.00	74.00	0.09	0.11	1.04	1.13
11	Bilgodu-I	691	442	147650	94444	15	9	60	44	3.19	3.17	69.23	0.09	0.10	1.28	0.94
12	Kalavan-I	413	536	81299	105512	8	11	54	61	3.47	3.45	78.26	0.13	0.11	1.06	1.20
13	Hejani-II	324	327	62548	63127	6	6	49	50	3.27	3.37	70.71	0.15	0.15	0.95	0.97
14	Katlekan(MG)-VI	723	412	134888	76866	13	8	63	53	3.35	3.49	72.41	0.09	0.13	1.18	0.99
15	Katlekan(MG)-II	767	446	140734	81835	14	8	50	52	3.04	3.15	66.67	0.07	0.12	0.92	0.95
16	Hejani-I	431	365	76418	64716	8	6	43	44	3.33	3.26	73.56	0.10	0.12	0.76	0.78
	Average	**470**	**409**	**110680**	**98836**	**11**	**10**	**45**	**45**	**2.91**	**2.96**	**69.71**	**0.11**	**0.13**	**1.08**	**1.06**
	Maximum	**868**	**1114**	**238462**	**327647**	**24**	**33**	**63**	**61**	**3.47**	**3.49**	**81.16**	**0.19**	**0.23**	**1.48**	**1.32**
	Minimum	**220**	**137**	**62548**	**40058**	**6**	**4**	**33**	**31**	**1.11**	**1.10**	**56.25**	**0.04**	**0.03**	**0.76**	**0.78**

Table 2 contd...

Table 2 contd....

Details of large gaps and forests

Sl No	Name of the sampling site	No of individuals in measured area		No of individuals / ha		Seedling density No. of individuals / m^2		No of species in measured		Species diversity (H) in measured		Similarity index (SI, %) between gap and forest	Index of species richness (s/n, s = No. of species, n = No. of individuals in measured area)		Species density (No. of species / Measured area)	
		Gap	Forest	Gap	Forest	Gap	Forest	Gap	Forest	Gap	Forest		Gap	Forest	Gap	Forest
1	Bilgodu-II	666	652	100604	98489	10	10	60	51	3.23	3.09	72.07	0.09	0.08	1.00	0.93
2	Gijaguni-III	738	485	112672	74046	11	7	59	57	2.69	3.13	65.52	0.08	0.12	0.99	1.00
3	Katlekan (MG)-V	810	769	136364	129461	14	13	61	58	3.34	2.78	80.67	0.08	0.08	1.03	0.98
4	Kodigadde-III	742	693	134909	126000	13	13	55	51	3.19	2.96	71.70	0.07	0.07	0.90	0.87
5	Basavanabailu	677	825	115136	140306	12	14	58	59	3.23	3.07	82.05	0.09	0.07	0.79	0.71
6	Kodigadde-V	722	1203	102849	171368	10	17	63	59	2.96	2.57	75.41	0.09	0.05	0.91	0.77
7	Katlekan (MG)-I	657	555	84774	71613	8	7	56	55	3.22	3.40	73.87	0.09	0.10	0.90	0.84
8	Kodigadde-I	741	701	112273	106212	11	11	52	47	3.23	2.99	70.71	0.07	0.07	0.69	0.69
9	Kodigadde-II	858	775	119167	107639	12	11	50	50	3.07	2.83	76.00	0.06	0.06	0.72	0.71
10	Mastimane	1319	1316	91597	91389	9	9	71	80	3.22	3.35	76.82	0.05	0.06	0.49	0.56
11	Katlekan (MG)-VII	1863	1640	94091	82828	9	8	80	83	3.39	3.62	83.44	0.04	0.05	0.40	0.42
	Average	**890**	**874**	**109494**	**109032**	**11**	**11**	**60**	**59**	**3.16**	**3.07**	**75.30**	**0.07**	**0.07**	**0.80**	**0.77**
	Maximum	**1863**	**1640**	**136364**	**171368**	**14**	**17**	**80**	**83**	**3.39**	**3.62**	**83.44**	**0.09**	**0.12**	**1.03**	**1.00**
	Minimum	**657**	**485**	**84774**	**71613**	**8**	**7**	**50**	**47**	**2.69**	**2.57**	**65.52**	**0.04**	**0.05**	**0.40**	**0.42**

Table 3. Comparison of number of species, number of individuals, species diversity index, Similarity index values, index of species richness and species density in measured gap and forest area

Sl No	Parameter	t-statistic	t- tabulated
I	Comparison of the following between small(<200 m^2 , n_1=16) and large(>200m^2 , n_2=11) measured gap		
	➢ No of species	4.39**	$t_{.05}$(2,25=2.06
	➢ No of individuals	3.75**	
	➢ Species diversity index	1.26	
	➢ Species similarity index **(SI)**	2.49*	$t_{0.01}$(2),25=2.787
	➢ Index of species richness **(s/n)**	2.91*	
	➢ Species density (No.of species / Area)	3.53**	
II	Comparison of the following between small (<200 m^2, n_1=16) and large (> 200m^2, n_2=11) measured forest area		
	➢ No of species	3.86**	
	➢ No of individuals	4.19**	
	➢ Species diversity index	0.61	
	➢ Similarity index **(SI)**	2.49*	$t_{0.05}$(2),25=2.06
	➢ Index of species richness(**s/n**)	3.64**	$t_{0.01}$(2),25=2.787
	➢ Species density (No.of species / Area)	4.280**	
III	Comparison of the following between small gap and small forest area (n_1= n_2=16)		
	➢ No of species	0.30	
	➢ No of individuals	0.80	
	➢ Species diversity index	0.22	$t_{0.05}$(2),30=2.04
	➢ Index of species richness(**s/n**)	1.04	$t_{0.01}$(2),30=2.75
	➢ Species density (No.of species / Area)	0.358	
IV	Comparison of the following between large gap and large forest area (n_1=n_2=11)		
	➢ No of species	0.31	
	➢ No of individuals	0.11	$t_{.05}$(2),20=2.086
	➢ Species diversity index	0.82	
	➢ Index of species richness(**s/n**)	0.05	$t_{.01}$(2),20=2.845
	➢ Species density (No.of species / Area)	0.376	

Note: ' * ' and '**' indicate, statistically significant at 5% and 1% level respectively.

Table: 4. Details of correlation co-efficient ' r 'values for number of species, individuals and species diversity in gap and forest area.

Attributes	Correlation r-value	r-tabulated
In Small measured gaps and forests (<200 m²), n=16		
I) Correlation of the following with **measured gap area**		
a) Number of species in gaps	0.63**	$r_{0.05(2),14}=0.497$
b) Number of individuals in gaps	0.34	$r_{0.01(2),14}=0.623$
c) Diversity index in gaps	0.45	
II) Correlation of the following with **measured forest area**		
a) Number of species	0.73**	$r_{0.05(2),14}=0.497$
b) Number of individuals	0.06	$r_{0.01(2),14}=0.623$
c) Diversity index	0.56*	
III) Correlation of **similarity index** with **measured gap / forest area**	0.20	$r_{0.05(2),14}=0.497$
In Large measured gaps and forests (>200 m²), n=11		
I) Correlation of the following with **measured gap area**		
a) Number of species in gaps	0.88**	$r_{0.05(2),9}=0.602$
b) Number of individuals in gaps	0.97**	$r_{0.01(2),9}=0.735$
c) Diversity index in gaps	0.36	
II) Correlation of the following with **measured forest area**		
a) Number of species	0.91**	$r_{0.05(2),9}=0.602$
b) Number of individuals	0.85**	$r_{0.01(2),9}=0.735$
c) Diversity index	0.72*	
III) Correlation of **Similarity index** with **measured gap / forest area**	0.48	$r_{0.05(2),9}=0.602$

Note: ' * ' indicates, statistically significant at 5% level, ' ** 'indicates, statistically significant at 1 % level , without '*' no significant correlation.

Table 5. Number of species under different life form category in measured small and large gaps and forests

A. Number of species under a life form category in small measured sites

	Small measured Gap						Small measured Forest					
	Tree	Shrub	Liana	Climber	Herb	Unknown	Tree	Shrub	Liana	Climber	Herb	Unknown
Total	93	40	6	18	7	2	87	41	4	17	5	1
%	56	24	4	11	4	1	56	26	3	11	3	1
Average	24	11	1	6	3	0	24	11	1	6	2	0
%	52	24	2	14	6	1	53	25	3	14	5	1
Maximum	37	17	3	8	5	1	30	16	3	11	3	1
%	59	31	5	19	11	4	62	30	8	20	7	3
Minimum	17	5	0	3	0	0	14	6	0	4	0	0
%	46	17	0	8	3	0	44	18	0	10	2	0

B. Number of species under a life form category in large measured sites

	Large measured Gap						Large measured Forest					
	Tree	Shrub	Liana	Climber	Herb	Unknown	Tree	Shrub	Liana	Climber	Herb	Unknown
Total	97	36	5	19	8	5	96	35	4	16	5	3
%	57	21	3	11	5	3	60	22	3	10	3	2
Average	33	13	1	9	4	1	34	13	1	8	3	1
%	57	21	3	13	5	1	58	21	3	13	4	1
Maximum	44	19	2	12	6	3	48	20	3	10	5	2
%	63	28	6	16	9	3	68	30	6	22	8	3
Minimum	27	9	1	7	2	0	25	9	1	5	1	0
%	48	15	2	11	0	0	49	16	2	9	0	0

Table 6. Number of individuals and their percentage under different life forms in measured small and large gaps and forest areas.

A. Number of individuals and their percentage under different life forms in small measured area.

	Small Gap sites						Small Forest sites					
	Tree	Shrub	Liana	Climber	Herb	Unknown	Tree	Shrub	Liana	Climber	Herb	Unknown
Maximum	761	219	28	128	154	16	967	190	20	157	134	11
Minimum	53	63	2	10	2	1	45	40	1	10	3	2
Average	247	113	11	55	49	4	214	106	10	55	31	7
%	52	24	2	12	10	1	51	25	2	13	7	2

B. Number of individuals and their percentage under different life forms in large measured area

	Large Gap sites						Large Forest sites					
	Tree	Shrub	Liana	Climber	Herb	Unknown	Tree	Shrub	Liana	Climber	Herb	Unknown
Maximum	556	871	70	197	197	74	776	547	60	365	131	35
Minimum	124	192	2	46	3	1	169	148	4	30	3	1
Average	339	353	20	86	81	16	465	287	25	127	49	13
%	38	39	2	10	9	2	48	30	3	13	5	1

Fig. 1. Percent of species in different life forms in small and large measured gap and forest area

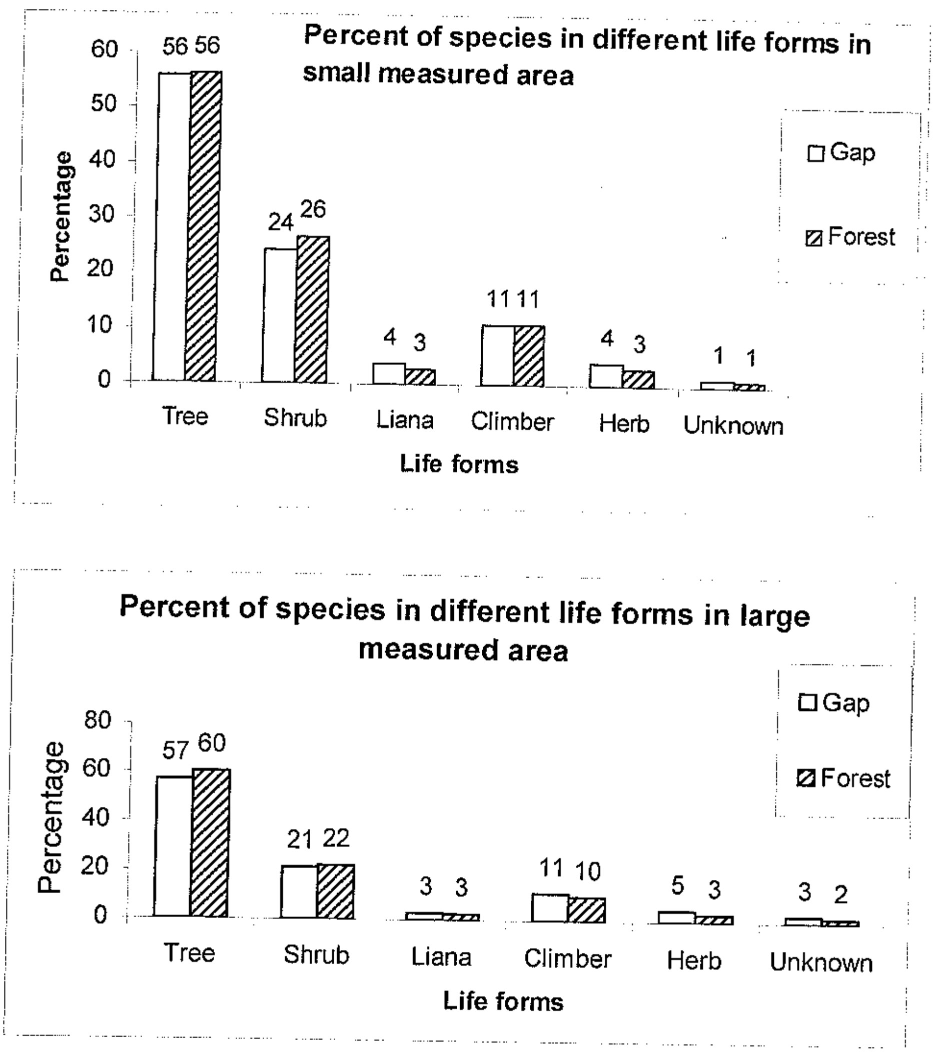

Fig. 2. Percentage of individuals indifferent life forms in small and large measured gap and forest area