PLANT DIVERSITY ASSESSMENT OF *SHOREA ROBUSTA* DOMINATED FOREST STANDS OF SIMILIPAL BIOSPHERE RESERVE

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The present study was undertaken to assess the plant diversity of *Shorea robusta* dominated forest stands of Similipal biosphere reserve in Orissa. Species diversity index, concentration of dominance and species richness of tree, shrub and herb layers and regeneration status of tree species were calculated from the data obtained by carrying out study on phytosociology. The study was conducted in six different forest sites dominated by *Shorea robusta* in northern tropical moist deciduous forest of the reserve at elevations ranging from 80-824m. Plants were categorized into different cbh classes viz. <10cm, 10-31cm,32-66cm, 67-101cm, 102-136cm, 137-171cm and >171cm to assess their regeneration potential among the study sites. Correlation and regression analysis was used to evaluate the relationship between different diversity indices of the plant communities. It was found that anthropogenic disturbances are changing the analytical characters (density, basal area, frequency, abundance, A/F ratio) as well as the synthetic characters (species richness, species diversity, concentration of dominance, etc.) of the tree, shrub and herb layers of the reserve. The species diversity and species richness of the tree, shrub and herb layers were greater at the unprotected (buffer) sites than at the protected (core) site. However, the density and basal area of the tree layer showed the reverse pattern. The study also revealed the presence of good number of individuals of various woody species in different cbh classes, which indicates that their regeneration is good. There were greater number of individuals in the higher cbh classes compared to the lower cbh classes in the protected site but it was not so in the buffer zone of the biosphere reserve.

Key words : Anthropogenic disturbance, Distribution pattern, Diversity, Dominance, Importance Value Index (IVI), Regeneration, Species composition

Tropical forests are amongst the richest and most complex biological communities on the earth and exhibit a tremendous ability of self-maintenance. The increasing population pressure over the last few decades and dependence of the people on plant products has led to the vast exploitation of natural flora of these forests. The impact of increasing human activities on the plant diversity might influence the ecosystem functioning (Wilson, 1992), which has triggered interest in the studies related to the effect of diversity on ecosystems (Schulze and Mooney, 1993) and ecosystem services (Daily, 1997).

The study area i.e. Similipal Biosphere Reserve (SBR) is one of the 12 Indian biosphere reserves created under the Man and Biosphere Programme. It covers about 4374 km^2, out of which a vast area is covered by dry deciduous forest to moist deciduous forest. The vegetation is generally classified as northern Indian tropical moist deciduous type (Champion and Seth, 1968). Besides having 64 species of cultivated plants, SBR harbours 1012 other plant species, which belongs to168 families of vascular plants (Saxena and Brahmam, 1989). The plant diversity of SBR has been studied both qualitatively and quantitatively by different workers (Panigrahi *et al.*, 1964; Saxena and Brahmam, 1989; Swain and Nanda, 1989; Mishra *et al.*, 2003). In the wake of efficient socio-economic development for the betterment of soil, livestock and human beings, the conservation of plant diversity in the SBR assumes a great deal of significance. The aim of the present investigation is to assess and describe plant species richness and diversity in relation to anthropogenic disturbance in a few *Shorea robusta* -dominated forest stands of SBR and also to understand the regeneration status of the tree species.

MATERIALS AND METHODS

Location and climate

The study area (SBR) is located in the district of Mayurbhanj in Orissa between 86^0 04$'$ to 86^0 37$'$ E

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Table-1: Characteristic features of the study sites

Site	Aspect	Elevation	Normal plants	Damaged plants	Total (Normal +Damaged)	D.I (%)	Level of interference
S-1 (Podadiha)	South-East	80	109	84	193	43.52	HB
S-2 (Lulung)	East	120	120	83	203	40.89	HB
S-34 (Kalika Prasad)	West	468	138	44	182	24.17	MB
S-4 (Gurguria)	North-West	614	136	43	179	24.02	MB
S-5 (Nawna)	North-East	730	140	40	180	22.22	MB
S-6 (UBK)*	South	824	186	36	222	16.22	NB

D.I. (Disturbance Index)= Percentage of damaged individuals of the total number of woody individuals per 2000 m^2 area

* UBK- Upper Barakamda

HB- High biotic interference; MB-Moderate biotic interference; NB- No biotic interference.

longitude and 21^0 28′ to 22^0 08′ N latitude. The altitude ranges between 80 and 1165m asl. The climate is influenced by monsoon pattern of rainfall. Generally, the area receives over 3450mm annual rainfall; three-fourth of this occurs in the rainy season (mid-June to mid-September). Average minimum temperature ranges from 7.2 ^{0}C to 11.1 ^{0}C and average maximum from 33.4 ^{0}C to 37.4^{0}C (Srivastava and Singh, 1997). March, April and May are generally dry.

After a reconnaissance survey of the reserve six sites were selected (Table-1) based on their accessibility, extent of distribution, elevation and degree of biotic disturbance.

VEGETATION ANALYSIS

The tree layer was analysed using 20 randomly laid quadrats (10m x 10m) at each of the six study sites. Circumference at breast height (cbh 1.37m from the ground) was measured for all the trees and saplings and recorded individually by species. Similarly, 20 quadrats of 5m x 5m were laid for studying the shrubs and saplings and 20 quadrats of 1m x 1m for herbs and seedlings (Kershaw, 1973; Misra, 1968). The individuals having more than 31cm cbh were categorized as trees, those having 10-31cm cbh as saplings and those having <10cm cbh were regarded as seedlings. The phytosociological data collected through quadrat studies were used for determining frequency, density, abundance following Misra (1968) and abundance to frequency ratio (A/F). The degree of disturbance of the study sites was analysed following Pandey and Shukla (1999). The Importance Value Index (IVI) for the tree layer was determined as the sum of the relative frequency, relative density and relative dominance (Misra, 1968) for each species. Tree crown area was measured by taking two diameters at right angles to each other across the canopy of the plants, one of which represented the maximum diameter for the tree canopy and the other minimum. The average of these two diameters represented the mean crown diameter. The crown area of each tree/shrub was calculated using the following formula:

$A = D^2/4$, where, D is the average crown diameter.

The trees were categorized into five **cbh** classes: 32-66, 67-101, 102-136, 137-171 and >171cm for the analysis of population structure. The total number of individuals belonging to these **cbh** classes and to the sapling and seedling categories was calculated. The relative density of each class was calculated following Knight (1975) as given below:

$$\text{Relative density} = \frac{\text{Total number of individuals in a girth class of a species}}{\text{Total number of individuals of all girth classes of all species on a site}} \times 100$$

Diversity index for different layers at each study site was calculated following Shannon and Wiener (1963) and concentration of dominance following Simpson (1949). Species richness was determined as the number of species per unit area (Whittaker, 1975).

RESULTS AND DISCUSSION

Inventory of vascular plants

A total of 273 species of angiosperms belonging to 135 genera and 61 families was recorded. They represented approximately 27% of the estimated flora of Similipal (Saxena and Brahmam, 1989). There was a considerable difference in the number of species among the study sites, site-1 being the richest having 56 species (Table-2). All other sites differ widely in terms of number of species. The pattern indicates that lower elevation sites have more species than higher elevation sites. The high degree of anthropogenic disturbance prevailing at the lower elevational study sites promoted species richness, possibly by allowing several species to maintain their population in the open canopy (Table-4). Besides this, the analysis of variance indicated that the species richness was significantly different among the different vegetation layers (F= 173.7, P£ 0.001) as well as between the sites (F=9.1, P£ 0.01).

Table-2 : Species richness for all vegetational layers at different sites of Similipal biosphere reserve.

Site	Tree layer	Shrub layer	Herb layer	Total
S-1	28	12	16	56
S-2	29	9	16	54
S-3	23	7	12	42
S-4	22	6	15	43
S-5	22	7	14	43
S-6	19	4	12	35

ANOVA

Between vegetation types (F= 173.7, P £ 0.001)

Between sites (F= 9.1, P £ 0.01)

Structure of vegetation

Importance Value Index (IVI) of tree species indicated that *Shorea robusta* was the dominant species at all the study sites in the tree, shrub and sapling layers of the reserve (Table-3a and 3b). This species had IVI value ranging 80-150 at study sites located below 850m elevations. In the forests of Central Himalaya, Tewari and Singh (1987) reported an IVI value of 127 for *S. robusta* in mixed forests (300-900m) and 181 in pure forest of *S. robusta* (up to 1100m). Sunderpandian and Swamy (2000) did not find Dipterocarpaceous members at altitudes above 1150m. Burges (1961) found that with the increase in steepness of slopes and elevation, there is a reduction in frequency of Dipterocarps. This may be due to the change in species composition with altitude (Procter et al., 1988). The IVI of *S. robusta* in the present study is well within the range reported by different workers in *S. robusta* dominated forest stands in India.

The crown cover across the study sites ranged from 9.07 to 27.24 %. Sites 5 and 6 had the highest crown

Table-3a Importance Value Index (IVI) of tree species (common to at least two sites) of Similipal biosphere reserve

Name of the plant species	S-1	S-2	S-3	S-4	S-5	S-6
Shorea robusta Gaertn.f.	80.158	104.279	149.922	119.083	122.585	130.15
Buchanania lanzan Spreng.	6.568	2.677	9.840	-	1.897	-
Terminalia alata Heyne ex Roth.	29.226	5.582	3.162	24.706	17.464	46.57
Schleichera oleosa (Lour.)Oken.	15.103	6.358	-	4.756	-	-
Adina cordifolia (Roxb.)Hook.F.ex Brandis	7.848	8.247	8.317	14.546	4.311	-
Croton roxburghii Balak	8.398	-	-	-	4.401	-
Diospyros melanoxylon Roxb.	8.067	2.536	6.358	-	-	-
Anogeissus latifolia (Roxb.Ex.DC.) Wall ex Bedd.	14.220	24.263	11.636	20.395	16.585	-
Securinega virosa (Roxb.Ex Willd)Baill	12.997	2.568	-	-	-	-
Madhuca latifolia Roxb.	7.453	13.442	11.296	-	-	-
Diospyros embryopteris Pers.	3.610	-	-	3.795	-	-
Protium serratum (Wall ex Colebr.) Engl.	11.845	-	7.827	13.262	26.027	8.03
Careya arborea Roxb.	8.551	7.218	2.539	-	-	1.94
Dillenia pentagyna Roxb.	14.155	-	8.114	7.354	5.521	20.58
Gmelina arborea Roxb.	4.124	5.582	-	2.625	-	9.64
Bridelia retusa (L.) Spreng.	4.869	-	2.08	7.226	-	-
Accacia leucophloea (Roxb.) Willd.	1.919	-	6.116	-	-	-
Terminalia chebula Retz.	3.033	15.401	2.532	-	-	-
Syzygium cerasoides (Roxb.) Raizada	-	6.531	9.336	11.027	4.941	14.05
Syzygium cumini (L.) Skeels	-	5.636	14.711	4.051	-	12.12
Albizia marginata (Lam.)Merr.	-	2.474	12.083	3.498	7.52	-
Mangifera indica L.	-	6.064	-	10.897	-	3.32
Bombax ceiba L.	-	3.391	-	-	-	-
Aegle marmelos (L.)Corr.	-	2.905	2.195	-	9.737	-
Stereospermum suaveolens (Roxb.)DC.	-	2.280	2.265	2.302	-	-
Pterocarpus marsupium Roxb.	-	-	13.548	12.807	1.955	5.66
Lagerstroemia parviflora Roxb.	-	-	6.167	-	9.081	-
Desmodium oojeinensis (Roxb.) Ohashi	-	-	2.278	4.097	5.955	-
Hymenodictyon excelsum (Roxb.) Wall.	-	-	-	5.981	28.818	-
Nyctanthes arbor-tristis L.				3.803	-	2.26
Bauhinia purpurea L.	-	-	-	-	7.291	3.52
Casearia graveolens Dalz.	2.804	-	-	-	-	1.77

Table-3b Importance Value Index (IVI) of tree species found only on one site of Similipal biosphere reserve

Name of the plant species	S-1	S-2	S-3	S-4	S-5	S-6
Lannea coromandelica (Houtt.)Merr.	9.776					
Semecarpus anacardium L.f.	4.379					
Dalbergia latifolia Roxb.	9.663					
Tectona grandis L.f.	6.816					
Xantolish tomentosa (Roxb.) Raf.	3.253					
Ixora sp.	3.046					
Catunaregum spinosa (Thunb.) Tirveng.	2.215					
Holarrhaena antidysenterica (Roth.) A.DC.	3.504					
Wendlandia tinctoria (Roxb.) DC.	3.609					
Albizia lebbeck (L.) Benth.		14.148				
Gardenia gummifera L.f.		2.489				
Terminalia arjuna (Roxb.Ex.DC.) Wight & Arn.		0.06				
Samanea Saman (Jacq.) Merr.		6.06				
Butea monosprma (Lam.)Taub.		4.65				
Xylia xylocarpa (Roxb.) Taub.		15.021				
Ficus benghalensis L.		3.221				
Ficus religiosa L.		12.146				
Miliusa velutina (Dunal) Hook.f. & Thomas.		2.403				
Terminalia bellirica (Gaerth.) Roxb.		5.186				
Madhuca indica Gmel.			11.296			
Albizia procera (Roxb.)Benth			1.954			
Saraca indica (Roxb.) de Wilde				4.843		
Bauhinia vareigata L.				8.718		
Albizia odoratissima (L.f.) Benth.					5.204	
Barringtonia acutangula (L.) Gaertn.					6.422	
Wendlandia sp.					1.873	
Phyllanthus emblica L.					2.864	
Trichilia connaroides (W. & A.)Bentv.					4.098	
Vitex leucoxylon L.f.					4.532	
Michelia champaca L.						4.34
Artocarpus lacucha						7.34
Bauhinia malabarica						13.91
Homalium nepalens						2.76
Ligustrum gamblei						5.26
Ochna obtusata						5.61
Prunus ceylanica						6.15
Cassia fistula L.	-	-	-	10.262	-	-

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Ochna obtusata						5.61
Prunus ceylanica						6.15
Cassia fistula L.	-	-	-	10.262	-	-

cover (Table-4). The sites situated farther from the human habitation had high crown cover, while the sites situated in the vicinity of human habitation had low crown cover. Forests around human habitation are lopped frequently for fodder and fuel wood, and could be one of the reasons for the low crown cover in such forests (Jeet Ram *et al.*, 2004). Total shrub and herb species richness significantly decreased with

Table-4: Tree crown cover at different study sites in Similipal biosphere reserve.

Site	Total tree crown cover (m^2/ ha)	Percentage of tree crown cover
S-1	15078.7	9.07
S-2	24139.2	14.52
S-3	24621.1	14.81
S-4	24887.35	14.97
S-5	32218.85	19.38
S-6	45285.95	27.24

increasing tree crown cover (r = -0.828, P £ 0.01 and r = -0.680, P £ 0.05 for shrubs and herbs, respectively). Jeet Ram et al. (2004) have also reported such type of correlation for tree species of Uttaranchal in Central Himalaya. The total basal area across the sites ranged from 52.37 to 84.86m^2 ha^{-1} and the total tree density from 680 to 970 plants ha^{-1} (Table-5). The difference in basal area and density of tree layer among sites may be attributed to difference in altitude, species composition, age of trees, and degree of disturbances and successional stages of the stand. Singh et al. (1994) have reported 18-92 m^2 ha^{-1} total basal area and 610-1670 plants ha^{-1} total tree density in *Shorea robusta* dominated forests of Kumaun Himalaya. In the present study the values obtained for basal area and tree density have similar range. It was also noticed from the present investigation that the tree density and basal area were positively correlated with altitude (r = 0.645 for tree basal area and 0.659 for density) though the correlation was statistically insignificant. However, density of shrubs and herbs was negatively correlated (r = -0.719, P £ 0.05 and –0.970, P £ 0.01 for shrubs and herbs, respectively).

Table –5 Plant density, total basal area (TBA) and percentage of species in the tree, shrub and herb layers showing different distribution patterns at six different study sites of Similipal biosphere reserve.

Site	Component	Density (x 1000 plants / ha)	TBC (m^2/ha)	Distribution pattern (%)		
				Regular	Random	Contiguous
S-1	Tree	0.680	52.36	17.24	54.48	48.27
	Shrub	1.560	-	4.35	39.13	56.52
	Herb	486.00	-	0.00	0.00	100.00
S-2	Tree	0.735	59.78	13.79	37.93	48.27
	Shrub	1.540	-	4.00	12.00	84.00
	Herb	456.00	-	0.00	0.00	100.00
S-3	Tree	0.750	78.61	8.69	34.78	56.52
	Shrub	1.450	-	12.5	25.00	62.50
	Herb	144.00	-	0.00	0.00	100.00
S-4	Tree	0.740	63.45	4.54	36.36	59.09
	Shrub	1.620	-	13.33	20.00	66.67
	Herb	160.00	-	0.00	0.00	100.00
S-5	Tree	0.735	61.04	9.09	31.82	59.09
	Shrub	1.200	-	5.55	22.22	72.22
	Herb	74.00	-	0.00	9.1	90.9
S-6	Tree	0.970	84.86	5.00	20.00	75.00
	Shrub	1.050	-	4.35	8.69	69.56
	Herb	63.00	-	0.00	0.00	100.00

DISTRIBUTION PATTERN

The A/F ratio indicates that most of the species at the selected sites were contiguously distributed (Table-5). Odum (1971) stated that contiguous distribution is most common in natural conditions. Preponderance of regular as well as random distribution reflects the magnitude of biotic disturbances or interferences (Varghese and Menon, 1999). Only a small percentage of shrubs and herbs showed a regular distribution. Such condition may not only be depending upon the reproductive condition, but also is related to other factors like vegetative, and climatic conditions. According to Chandra *et al.* (1989) the contiguous distribution is due to multitude of factors.

DIVERSITY

The species diversity ranged from 1.798 to 2.287 for tree layer, 1.432 to 2.103 for shrubs and from 2.084 to 2.519 for herb layer (Table-6). The diversity index is generally high for tropical forests, and the reported range is 5.06 and 5.4 for young and old strands, respectively (Knight, 1975). Many researchers have reported the diversity value for Indian tropical forests in the range of 0.83 to 4.1 (Parthasarathy et al., 1992; Visalakshi, 1995). The diversity value obtained in the present study is well within the reported range for Indian tropical forests. The correlation between species diversity of tree, shrub and herb layers with altitude was always found to be negative (r = -0.331, -0.885 and -0.922 for tree, shrub and herb layers, respectively). Out of these correlations, the correlation between tree species diversity and altitude was found statistically insignificant, while the correlation between shrub species diversity with altitude and herb species diversity with altitude was statistically

Table-6 Species diversity (H') and concentration of dominance (cd) for tree, shrub and herb layers of Similipal biosphere reserve.

Site	Species (H') Diversity			Concentration of dominance (Cd)		
	Tree	Shrub	Herb	Tree	Shrub	Herb
S-1	2.139	2.103	2.519	0.214	0.089	0.117
S-2	2.153	1.995	2.481	0.206	0.098	0.117
S-3	1.994	1.851	2.152	0.313	0.092	0.139
S-4	2.133	1.812	2.149	0.254	0.123	0.135
S-5	2.287	1.796	2.226	0.103	0.135	0.147
S-6	1.798	1.432	2.084	0.316	0.171	0.199

ANOVA
Between vegetation types (F= 23.04, P £ 0.001)
Between sites (F= 7.184, P £ 0.01)

significant at P £ 0.001. Jeet Ram *et al.* (2004) observed similar correlation between altitude and tree species diversity of forest types of Uttaranchal, and Chandra *et al.* (1989) for herbaceous species along an altitudinal gradient in Central Himalayan forests. Besides this, it was also observed from the present investigation that the species diversity was significantly different among the vegetation layers (F = 23.04, P £ 0.001) and between the sites (F = 7.184, P £ 0.01). Whittaker (1972) stated that the dominance of one stratum might affect the diversity of another stratum. Saxena and Singh (1982) observed decrease in the herb diversity with increasing total tree basal area and stated that there exists a negative relationship between these two parameters. In the present study the relationship between diversity of shrubs and herbs with the basal area of tree species was negative and the correlation (r = -0.831 and –0.799 for shrubs and herbs, respectively) was significant at P£ 0.01.

The concentration of dominance is inversely related with species diversity. The dominance value across the sites and strata ranged from 0.103 to 0.316, 0.089 to 0.171 and from 0.117 to 0.199 for trees, shrubs and herbs, respectively (Table-6). These values for various layers of vegetation are not very different from earlier reports from Orissa (Verma *et al.*, 1996). The relationship between the species diversity and concentration of dominance for each vegetation layer of the study sites was statistically significant and the correlation between these two parameters was always negative (r = -0.884, -0.922 and –0.787 at P £ 0.01 for trees, shrubs and herbs, respectively).

Tree species richness and the total species richness decreased with increasing elevation. The species richness reflects the species diversity. Shaukat *et al.* (1981) stated that species richness incorporated divergence index diversity. In Similipal Biosphere Reserve it was noticed that the species richness of tree, shrub and herb layers was positively correlated with species diversity (r = 0.486, 0.926 and 0.838 for tree, shrub and herb layers, respectively). Out of these correlations, the correlations between species richness of shrubs and their species diversity were statistically significant at P £ 0.01, and the same was true in case of herbs. However, correlation between tree species richness and tree species diversity was insignificant. It was also found that both species richness (r = -0.973, -0.903 and –0.712 for tree, shrub and herb layers, respectively) and species diversity were negatively correlated with altitude.

STRATEGIES OF WOODY TREE SPECIES RECRUITMENT

Although cbh distribution of tree species differs from site to site, and is largely controlled by the density of over-storey species, the pattern of regeneration can be roughly assumed by the size and diameter distribution as reported by Singh *et al.* (1986) and Khan *et al.* (1987). Density of individuals in different cbh classes of each study site is presented in Table-7. The population density of tree species in different cbh classes in different study sites indicated regeneration. The population of different age groups was in the order of seedling > sapling > bole > post bole > mature > over mature trees except at site-1. The maximum number of individuals was present in the seedling class i.e. < 10cm cbh. A comparision of the population size of different cbh class as among the study sites, indicated that site-6 had a greater number of individuals in the higher cbh classes i.e. 137-171cm and > 171cm and less number of individuals in the seedling category. The greater variation in the higher cbh class individuals among the study sites is due to the difference in protection measures adopted at different sites. Site-6 had greater number of individuals in the higher cbh class than in the lower cbh class individuals. This site is situated in the core zone of the reserve whereas other study sites are distributed in buffer areas of the Similipal Biosphere Reserve. The study establishes a clear pattern of decrease in herb and seedling density with increase in altitude. The higher girth class individuals were more numerous at the higher elevation sites compared

Table-7 Density(no.ha^{-1}) of tree species in different cbh classes in Similipal biosphere reserve.

	Site					
Girth class	S-1	S-2	S-3	S-4	S-5	S-6
	Density (Plants/ha)	Density (Plants/ha)	Density (Plants/ha)	Density (Plants/ha)	Density (Plants/ha)	Density (Plants/ha)
<10cm	62000 (95.62)	65500 (95.81)	61000 (95.63)	63500 (95.26)	55500 (95.79)	45500 (94.76)
10-31 cm	2160 (3.33)	2140 (3.13)	2040 (3.2)	2420 (3.63)	1700 (2.93)	1550 (3.23)
32-66cm	320 (0.40)	255 (0.37)	230 (0.36)	240 (0.36)	235 (0.41)	285 (0.59)
67-101cm	140 (0.22)	210 (0.31)	190 (0.3)	165 (0.25)	195 (0.34)	245 (0.51)
102-136cm	150 (0.23)	150 (0.22)	170 (0.27)	155 (0.23)	165 (0.28)	175 (0.36)
137-171cm	40 (0.062)	65 (0.095)	105 (0.16)	95 (0.14)	75 (0.13)	140 (0.29)
>171cm	30 (0.046)	45 (0.066)	55 (0.086)	85 (0.13)	65 (0.11)	120 (0.25)

Values in parentheses denote relative density

to the low elevation sites, which may be due to the closer canopy and less biotic disturbance at higher altitudes.

The forest sites of the SBR showed greater plant species diversity and floristic richness. The pattern of distribution of individuals in each cbh class at different study sites depicted that the regeneration was good. There was a decrease in number of individuals in higher girth classes in the buffer areas of the reserve in comparison to the core area. Further research on forest fragments along with disturbance sources and germination potential of tree species in natural conditions, needs to be undertaken to develop proper management plan for the biosphere reserve.

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