Khulna University Studies, 7(2): 37-44, 2006

RESEARCH ARTICLE **LIFE SCIENCE**

STATUS OF REGENERATION OF MAJOR TREE SPECIES IN THE SUNDARBANS

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KUS –05/31-231005

Manuscript received: October 23, 2005; Accepted: August 23, 2006

Abstract: Status of regeneration of 30 tree species in the Sundarbans has been provided based on data generated from 1203 Temporary Sample Plots (TSPs) during the Forest Resources Management Project (FRMP) Forest Inventory of the Sundarbans in 1996 and 1997. The extents of occurrence of individual species and mean number of seedlings and saplings per hectare have been provided which represents the whole of the Sundarbans. It was found that sundri (*Heritiera fomes*) constituted 54.92 % seedlings and 28.73 % saplings, while it was respectively 16.23 % and 19.64 % for gewa (*Excoecaria agallocha*) as well as 16.52 % and 44.36 % for goran (*Ceriops decandra*). Other species provided 12.33 % seedlings and 7.27 % saplings. Regeneration status of sundri, gewa, goran and amur (*Amoora cuculata*) of 1996-97 was compared with the data generated in January 2003 from 36 Sample Plots in 10 compartments of the Sundarbans. Comparison revealed that there occurred significant (p=0.05) increase in sundri and amur seedlings in 2003 as compared to 1996-1997 level.

Key words: Regeneration, **s**eedlings, saplings, sundri, gewa, goran, amur

Introduction

Regeneration is a precondition to recruitment and establishment of tree species in a natural forest as in the Sundarbans. Therefore, knowledge of the status of regeneration and recruitment is considered to be of vital importance from a management perspective, particularly in case of sundri (*Heritiera fomes*) in the background of the occurrence of extensive top dying of sundri in the Sundarbans (Chaffey *et al.*, 1985; Rahman, 1995; Rahman *et al.,* 2003). Siddiqi (1989) reported on the data on seedling regeneration collected from 12 permanent sample plots in 3 salinity zones (slight, moderate and strong) in the Bangladesh Sundarbans mangroves from 1981 to 1987 and found inadequate number of seedlings and the failure of the seedlings to survive and establish.

Siddiqi and Hussain (1994) reported that spotted deer (*Axis axis*) did not damage regeneration of sundri (*Heritiera fomes*), gewa *(Excoecaria agallocha)* and goran (*Ceriops decandra*). However, deer browsing was harmful to regeneration of baen (*Avicennia officinalis*), passur (*Xylocarpus mekongensis*), kankra (*Bruguiera sexangula*) and khalisha (*Aegiceras corniculatum*). Hossain *et al* (1998) found that in general regeneration of seedlings and saplings of sundri was the highest, followed by gewa, but sundri regeneration increased with increasing distance from the canal bank (i.e. with decreasing flooding and salinity) while regeneration of gewa decreased; tree occurrence of the two species showed the reverse trends. Regeneration of the other species was low or absent.

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DOI: https://doi.org/10.53808/KUS.2006.7.2.0531-L

Therefore, it is considered to be of vital importance to find out the status of regeneration and recruitment of the tree species in general with special emphasis on sundri that is by far the most important tree species in the Sundarbans. Such knowledge would be useful in the sustainable management of top dying sundri in particular and Sundarbans in general.

Materials and Methods

Regeneration data of tree species presented in this paper were obtained from the data generated in 1996 and 1997 during the Forest Resources Management Project (FRMP) Forest Inventory of the Sundarbans and those generated from investigation in January 2003 by the authors in 36 sample plots laid out at 12 landings in compartment nos. 2, 11, 19 (having two landings), 20, 22, 26, 33, 36 (having 2 landings), 37 and 40. The 36 sample plots were selected in such a way that 9 sample plots fell in areas of very little or no top dying of sundri (i.e. none), slight, moderate and severe top dying of sundri. The area of each sample plot was 20 m x 20 m. Five regeneration sub-plots, each with 2 m x 2 m, were selected from each sample plot in such a way that one sub-plot fell in the centre of the four quadrant of the sample plot and the fifth sub-plot was from the centre of the sample plot. Thus all the seedlings and saplings of all tree species were recorded separately from 5 x 36=180 sub-plots. Seedlings with R1 type regeneration indicate all seedlings having stem height of less than 1.3 m while saplings with R2 type regeneration indicate all saplings having stem height more than 1.3 m but diameter at breast height (dbh) of less than 2.5 cm, and R3 type saplings having height more than 1.3m and dbh more than 2.5 cm. FRMP regeneration data were collected from 1203 Temporary Sample Plots (TSPs) laid out in 55 compartments in the Sundarbans. Each TSP was of 1899 m^2 area in five sub-plots from which five circular regeneration sub-plots covering 15m^2 area were selected. Collected data are maintained in the TSP Database at Sundarban Biodiversity Conservation Project (SBCP). By using a programme of the Structured Query Language (SQL) regeneration data were retrieved from the TSP Database for 1203 TSPs.

Since the data were collected from different sizes regeneration sub-plots during the FRMP Forest Inventory in 1996 and 1997 and during January 2003 both the data were transformed to per hectare values by multiplying with necessary factor by using the Microsoft Excel 1997 programme. The two data sets were then compared to find out whether there occurred significant difference among the mean values through analysis of variance by using the SAS and Microsoft Excel programme and further compared using Duncan's Multiple Range Test (Duncan, 1955).

Results

Data of regeneration of seedlings and recruitment to saplings and poles were collected in January 2003 from the 45 regeneration sub-plots from each of the none, slight, moderate and severe top dying of sundri sample plots have been summarized in Table 1**.** Table 1 shows the height mean no. of sundri seedlings in 4 m^2 area of the sub-plots in all the four top dying severity classes (i.e. no top dying (none), slight, moderate and severe top dying) as compared to gewa, goran, amur and shingra.

Comparisons of the data of each of the recorded species from among the sub-plots of the sample plots from the four top dying severity classes have been done through analysis of variance and provided in Table 2.

Analysis shows that significant variations in regeneration data of January 2003 among the four top dying severity classes (i.e. none, slight, moderate and severe) in cases of R1 (i.e. seedling), R2 (i.e. saplings) and R3 (i.e. poles) of sundri, R1 and R3 type goran, and R1 type of shingra (Table 2). With a view to identify the trend of occurrence of seedlings and saplings from none, slight, moderate and severe top dying sample plots, Duncan's Multiple Range Test (Duncan, 1955) were carried out with the data of sundri R1 and R2 types, goran R1 type, and shingra R1 type from 180 sub-plots in 36 sample plots from 10 compartments in the Sundarbans (Table 3).

Table 1. Summarized data of mean number of regeneration of types R1, R2 and R3 in an area of 4 square meters of each of 45 sub-plots in 9 sample plots of all mangrove species recorded in each of four top dying severity classes (viz. none, slight, moderate and severe) in January 2003 in the Sundarbans.

Top dying severity class	No. of sample plots	No. of sub- plots	Sundri R1	Sundri R2	Sundri R3	Gewa R1	Gewa R2	Gewa R3	Goran R1	Goran R3	Amur R1	Amur R2	Amur R3	Shingrra R1
None	9	45	7.02	0.16	0.38	2.20	0	0.42	0.60	1.48	0.29	0.29	0.80	0.02
Slight	9	45	11.6	0.33	0.31	0.11	0.07	0.16	0.69	0	1.80	0.13	0.38	0
Moderate	9	45	21.0	1.42	1.56	9.13	0.51	1.33	0.24	0.02	1.49	0.04	0.18	0.16
Severe	9	45	11.8	1.04	2.31	0.82	0.22	0.51	0.02	0	0.64	0.27	0.42	0.13

Notes: Regeneration R1 = Stem less than 1.3 m in height; R2 = Stem of 1.3 m or more in height but d.b.h. less than 2.5 cm; R3 = Stem of 1.3 m or more in height and d.b.h. 2.5 cm or more; Goran R2, Shingra R2 and Shingra R3 have been excluded from this table as all values were zero.

It is seen from Table 3 that there occurred significantly (p= 0.05) higher number of seedlings (R1 type) and saplings (R2 type) of sundri in moderate top dying sample plots and there being no significant difference among the mean number of sundri per 4 m^2 area from none, slight and severe top dying sample plots. The above findings strongly suggest that the level of severity of top dying of sundri may have less impact on regeneration of seedlings and recruitment to saplings in the 10 compartments of the Sundarbans where the study were conducted in January 2003.

Table 2. Comparative F-value and level of significance obtained from comparison of the three levels of regeneration of R1, R2 and R3 among 45 sub-plots of each of the four top dying severity classes (viz. none, slight, moderate and severe) as observed in January 2003 at 12 landings in 10 compartments in the Sundarbans.

Species	R1		R2		R3	
	F-value*	Significance	F-value*	Significance	F-value*	Significance
Sundri	4.08	Significant	3.49	Significant	4.15	Significant
Gewa	2.13	Insignificant	2.53	Insignificant	1.77	Insignificant
Goran	2.97	Significant	-	-	7.23	Significant
Amur	2.31	Insignificant	2.23	Insignificant	0.46	Insignificant
Shingra	4.10	Significant	1.35	Insignificant	0.14	Insignificant
Pssur	2.69	Insignificant	-	-	-	-

Notes: * refers that all the F-values are with 3 and 176 (residual) degrees of freedom; - = no data.

Table 3. Summary of Duncan's Multiple Range Tests of the mean regeneration of seedlings and saplings from 180 sub-plots (each 4m^2) in 2003 from 36 sample plots, 9 from each of no top dying (i.e. none), slight, moderate and severe top dying of sundri from 10 compartments in the Sundarbans.

Parameter				
Sundri seedlings	7.02 (None)	11.60 (Slight)	11.82 (Severe)	21.07 (Moderate)
Sundri saplings	0.16 (None)	0.33 (Slight)	1.04 (Severe)	1.42 (Moderate)
Goran seedlings	0.02 (Severe)	0.24 (Moderate)	0.60 (None)	0.69 (Slight)
Shingra seedlings	0 (Slight)	0.13 (Severe)	0.16 (Moderate)	0.80 (None)
Passur seedlings	0 (severe)	0.11 (Moderate)	0.56 (Slight)	0.76 (None)

Note: Means underscored by the same dotted line do not differ significantly, while the remaining means differ significantly (p = 0.05) from these means.

The extent of occurrence of and mean number of seedlings and saplings of 30 tree species as determined from the data of 1203 TSPs drawn from 55 compartments in the Sundarbans in 1996 and 1997 from FRMP Forest Inventory of the Forest Department are provided in Table 4.

Table 4. Extent of occurrence of and mean number of seedlings and saplings of 30 species per hectare for the whole of the Sundarbans based on data of 1203 Temporary Sample Plots (TSPs) generated during FRMP Forest Inventory in 1996 and 1997.

Species	No. of TSPs where the species was found	% of TSPs with the species	Mean seedlings / ha	% of total seedlings of all species	Mean saplings per ha	% of total saplings of all species
Amur	493	40.98	597.76	1.76	214.30	3.01
Babul	4	0.33	0.59	0.00	0.00	0.00
Baen	61	5.07	194.24	0.57	29.29	0.41
Banjam	0	0.00	0.00	0.00	0.00	0.00
Baral	1	0.08	0.00	0.00	0.00	0.00
Batla	2	0.17	0.00	0.00	0.00	0.00
Bhola	38	3.16	29.12	0.09	17.92	0.25
Bonlichu	2	0.17	0.00	0.00	0.00	0.00
Bonnoty	1	0.08	9.76	0.03	0.00	0.00
Dhundhul	31	2.58	19.36	0.06	4.56	0.06
Doya	2	0.17	0.00	0.00	0.00	0.00
Gab	22	1.83	0.00	0.00	1.32	0.02
Gewa	1168	97.09	5500.58	16.23	1397.91	19.64
Golpata	0	0.00	0.00	0.00	0.00	0.00
Goran	733	60.93	5598.53	16.52	3156.65	44.36
Jhana	13	1.08	0.00	0.00	1.86	0.03
Jhao	3	0.25	184.48	0.54	0.00	0.00
Jir	18	1.50	0.00	0.00	2.99	0.04
Kankra	102	8.48	553.59	1.63	82.79	1.16
Karanja	9	0.75	19.36	0.06	0.00	0.00
Keora	28	2.33	0.00	0.00	22.23	0.31
Khalisha	17	1.41	0.00	0.00	11.74	0.16
Kirpa	22	1.83	0.00	0.00	2.55	0.04
Ora	3	0.25	48.48	0.14	0.00	0.00
Passur	170	14.13	87.36	0.26	21.54	0.30
Saddabaen	12	1.00	38.88	0.11	0.00	0.00
Shingra	183	15.21	1835.34	5.41	51.76	0.73
Sitka	4	0.33	0.00	0.00	0.00	0.00
Sundri	1054	87.61	18614.82	54.92	2044.76	28.73
Others	219	18.20	563.19	1.66	51.85	0.73
Total:			33895.44	100	7116.12	100

Notes:; Amur – *Amoora cuculata*; Babul – *Acacia nilotica*; Baen – *Avicennia officinalis*; Ban Jam – *Eugenia fruticosa*; Baral – *Intsia bijjuga*; Batla – *Excoecaria indica*; Bhola – *Hibiscus tiliaceous*; Bonlichu – *Walsura robusta*; Bonnoty – *Mallotus repandus*; Dhundhul – *Xylocarpus granatum*; Doya – *Mucuna gigantea*; Gab –*Diospyros peregrina*; Gewa – *Excoecaria agallocha*; Golpata – *Nypa fruticans*; Goran – *Ceriops decandra*; Jhana – *Rhizophora mucronata*; Jhao – *Tamarix indica*; Kankra – *Bruguiera sexangula*; Karanja – *Pongamia pinnata*; Keora – *Sonneratia apetala*; Khalisha – *Aegiceras coyniculatum*; Kirpa- *Lumnitzera racemosa*; Ora – *Sonneratia caseolaris*; Passur – *Xylocarpus mekongensis*; Sadabaen – *Avicennia alba*; Shingra – *Cynometra ramiflora*; Sitka – *Clerodendron inerme*; Sundri – *Heritiera fomes* ; Others = Include all unidentified species. Source: FRMP Forest Inventory Database

It is apparent from Table 4 that gewa had the highest extent of occurrence in 97.09 % of the 1203 TSPs. This was followed in decreasing extent by sundri in 87.61 % of TSPs, goran in 60.93 %, amur in 40.98 %, shingra in 15.21 %, passur in 14.13 %, kankra in 8.48 %, baen in 5.07 %, bhola in 3.16 %, dhundhul in 2.58 %, keora in 2.33 % of the 1203 TSPs. Other species occurred in still lower % in the 1203 TSPs. In consideration of the 55 compartments of the Sundarbans there

occurred on an average 33895.44 seedlings of all tree species per hectare (ha) during 1996 and 1997. Out of these the highest of 54.92 % seedlings were of sundri. This was followed in decreasing order by 16.52 % of goran, 16.23 % of gewa, 5.41 % of shingra, 1.63 % of kankra and still of lower % by other species. On an average 7116.12 saplings ha^{-1} of all tree species occurred in the Sundarbans in 1996 and 1997. Out of these the highest of 44.36 % belonged to goran. This was followed in decreasing order by 28.73 % of sundri, 19.64 % of gewa, 3.10 % of amur, 1.16 % of kankra, 0.73 % of shingra, 0.41 % of baen, 0.31 % of keora, 0.30 % of passur, 0.25 % of bhola, and still in lower % by other species (Table 4).

Table 4 also reveals that 89.43 % of the total seedlings and 95.74 % of the total saplings of all tree species belonged to sundri, gewa, goran and amur only. Therefore, these four species were selected to compare the status of regeneration of seedlings and recruitment to saplings in 1996 and 1997 with those obtained in 2003. For this purpose the data of seedlings and saplings of these four species obtained from the 180 regeneration sub-plots of compartment numbers 2, 11, 19, 20, 22, 26, 33, 36, 37 and 40 in 2003 were converted to per ha values. The regeneration data of sundri, gewa, goran and amur as obtained in 1996–1997 from the 174 Temporary Sample Plots (TSPs) out of the 1203 which fell in the above mentioned 10 compartments were converted to per ha values. Then variance analyses were carried out to compare the mean values of seedlings and saplings of each of sundri, gewa, goran and amur. The results are summarized in Table 5.

Analysis of variance shows that sundri had significantly (p =0.05) higher number of 32194.44 seedlings per ha in January 2003 as compared to 18302.95 seedlings in 1996 - 1997 in the compartment numbers 2,11, 19, 20, 22, 26, 33, 36, 37 and 40 in the Sundarbans. In case of amur seedlings substantial and significant (p = 0.05) increases were found to occur in 2003 as compared to that of 1996 -97 as we found 3371.69 amur seedlings in 2003 as against 849.26 amur seedlings in 1996-97 and 791.67 amur poles in 2003 as against 98.10 poles in 1996-97 (Table 5). It is also clear that higher number of gewa seedlings, amur saplings were found to occur in 2003 as compared to 1996-97 but the difference between the mean pairs were insignificant. In case of sundri saplings, gewa saplings and goran seedlings higher numbers were found to occur in 1996-97 as compared to those found in January 2003, but in all cases the differences were only insignificant.

Table 5. Comparison of the mean values of the data of seedlings and saplings of sundri, gewa, goran and amur per ha from (a) 180 sample plots in January 2003 during study of top dying of sundri with (b) data obtained from 174 Temporary Sample Plots (TSP data) during FRMP Forest Inventory in 1996-1997 in compartment numbers 2, 11, 19, 20, 22, 26, 33, 36, 37 and 40 in the Sundarbans.

Parameter	Mean seedlings/ sapling/ ha (2003)	Mean seedlings/ saplings/ ha (1996-1997)	F value	P value	Significance of difference of the means
Sundri seedlings	32194.44	18302.95	10.68699	0.001192	Significant
Sundri saplings	1847.22	2308.92	0.98707	0.321143	Insignificant
Gewa seedlings	7666.67	3682.55	1.15539	0.283160	Insignificant
Gewa saplings	500.00	841.94	2.79252	0.095594	Insignificant
Goran seedlings	972.22	1402.01	1.47007	0.226148	Insignificant
Goran saplings	0	855.66	32.40264	2.64E-08	Significant
Amur seedlings	3371.69	849.26	33.5229	1.56E-08	Significant
Amur saplings	458.33	374.30	0.598245	0.439768	Insignificant

Discussion

The present findings reveal that during 1996 and 1997 sundri represented the highest of 54.92 % of the seedlings of all tree species. Goran had the second highest of 16.52 % and gewa had 16.23 % of the seedlings. Shingra had 5.41 % followed by amur (1.76 %), kankra (1.63%), baen (0.57 %) and passur (0.26 %). The number of seedlings of sundri, goran, gewa, shingra, amur, kankra, baen, passur were 18615, 5599, 5500, 1835, 598, 554, 185 and 87 per ha respectively in consideration of the whole of the Sundarbans. Goran had the highest number of saplings and constituted 44.36 % followed by sundri of 28.73 %, gewa 19.64 %, amur 3.01 %, kankra 1.16 %, shingra 0.73 %, baen 0.41 %, keora 0.31 %, passur 0.30 %, and other species had still of lower percent of occurrence. The mean number seedlings of sundri, goran, gewa, shingra, amur, kankra, baen and passur were 18615, 5599, 5500, 1835, 598, 554, 185 and 87 ha^{-1} respectively.

Seedling regeneration study conducted in 12 Permanent Sample Plots (PSP) of Sundarbans found the average number of seedlings appearing annually was 35,625 ha^{-1}, but there was large variation in numbers between plots and years. Of the new seedlings, *H. fomes* made up 41.27% and *E. agallocha* 54%, with the remaining 4.73% belonging to 10 other species (Siddiqi, 1989). A decreasing trend with year was not observed, and there was no significant relation between regeneration status and standing tree density.

Helalsiddiqui (1999) reported a study conducted on the tree and sapling population of the major species of the Sundarbans mangrove forest of Bangladesh during 1996. Trees of >5 cm diameter at breast height (dbh) were enumerated in temporary sample plots in freshwater, moderately saline and strongly saline water zones. The numbers of major species differed between zones. The maximum number of species was in the moderately saline zone (12) and the minimum in the strongly saline zone (6), while the freshwater zone had 9 major species. *Sundri* (*H. fomes*), and gewa (*E. agallocha*), were dominant in the freshwater zone with 1925 and 1205 trees ha^{-1} and 34 080 and 18 293 saplings ha^{-1}, respectively. In the moderately saline zone sundri and gewa had 1040 and 666 trees ha^{-1} and 26 826 and 34 794 saplings ha^{-1}; corresponding numbers in the strongly saline zone were 224 and 3834 trees ha^{-1} and 6880 and 5280 saplings ha^{-1}, respectively.

Siddiqi (1999) reported the results of studies on regeneration of *Heritiera fomes* in permanent (1982-91) and temporary (1990-91) experimental plots in the Sundarbans. The average number of seedlings appearing in a year was 6680 ha-1, although recruitment density varied among different parts of the forests and from year to year. Of the many mangrove species in the area sundri alone constituted 24% of the recruits. Salinity of the area apparently influenced recruitment that decreased with increasing levels of salinity. Seedling half-life values for sundri in less, moderate and strongly saline zones were 13.7, 8.8 and 6.3 months, respectively. The relationship between seedling recruitment and stand density was insignificant.

Like Siddiqi (1989) and Helalsissiqui (1999) in the present study sundri seedlings have been found to be of the highest occurrence. But more prevalence of sundri seedlings is evident from the fact that 54. 92 % of all seedlings were found to be of sundri in the present study in contrast to that of 41.92 % sundri seedlings. Siddiqi (1989) recorded gewa 54%, with the remaining 4.73% belonging to 10 other species. But in the present study gewa was found to constitute 16.23 % and goran 16.52 % of the seedlings. The reason for this deviation might have been because the present study is based on regeneration data from 1203 TSPs from 55 compartments in comparison to only 12 PSPs used by Siddiqi (1989).

Helalsiddiqui (1999) reported from freshwater zone of Sundarbans 34,080 sundri 18,293 gewa saplings ha^{-1}, in the moderately saline zone 26,826 sundri and 34794 gewa saplings ha^{-1} and in the saline water zone 6,880 sundri and 5,280 gewa saplings ha^{-1}. In the present study for the whole of

the Sundarbans the number of sundri, gewa and goran saplings per ha were found to be 2045, 1398 and 3157 respectively. It has been found that there is considerable variation in occurrence of sundri seedlings, saplings, poles and trees among the 55 compartments in the Sundarbans. Rahman (2003) has reported the per hectare distribution of sundri seedlings, saplings, poles and trees in 55 compartments of the Sundarbans which reveals that per ha sundri seedlings varied from 38 in compartment 49 to 73631 in compartment 15; in case of sundri saplings 22 saplings in compartment 51 against 6131 saplings in compartment 21; similarly 36 sundri poles in compartment 51 but 2088 poles in compartment 10; and 0.16 sundri tree in compartment 49 but 324 sundri trees in compartment 15. Thus it can be said that variations in the number of seedlings and saplings of different mangrove species is associated with the use of sampling areas in various parts of the Sundarbans.

Conclusion

Numbers of seedlings and saplings per hectare and percent occurrence of each of 30 tree species for the whole of the Sundarbans have been provided. It can be recorded that sundri constituted 54.92 % seedlings and 28.73 % saplings, gewa represented 16.23 % seedlings and 19.64 % saplings, and goran had 16.52 % seedlings and 44.36 % of saplings. All the remaining 27 tree species collectively represented 12.33 % seedlings and 7.27 % saplings. A comparison of the regeneration data of sundri, gewa, goran and amur of 1996-97 with that generated in January 2003 from 36 sample plots in 10 compartments of the Sundarbans revealed that there has occurred significant (p = 0.05) increase in sundri and amur seedlings in 2003 as compared to 1996-1997 level.

Acknowledgements: The authors gratefully acknowledge the financial support provided by Sundarbans Biodiversity Conservation Project (SBCP) of Bangladesh Forest Department, Ministry of Environment and Forest under contract within the framework of its ADB/GEF fund for conducting research on Top dying of sundri (*Heritiera fomes*) and its management in the Sundarbans and the present paper is part of that study. We are also grateful to SBCP project authority for providing information on TSP Database without which the present study could not be completed. We are also grateful to Khulna University authority for providing necessary permission to carry out the study along with our obligations and commitments in Khulna University. We do also acknowledge the sweet company of Prof. A.K. Fazlul Haque and Dr. Khaled Misbahuzzaman during the work.

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