

SUNDARBAN BIODIVERSITY CONSERVATION PROJECT

Final Report On
**THE UNDERGROWTH SPECIES OF SUNDARBAN
MANGROVE ECOSYSTEM (BANGLADESH)**

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CHAPTER-1**1. INTRODUCTION**

Ecosystem health is presently defined as an environment that maintains its biodiversity, is stable over time, and is resilient to change or perturbation (Rapport, 1989). In order to measure ecosystem health, various approaches may be adopted to monitor: (i) the key environmental processes operating to maintain stable ecosystems, (ii) human impacted zones do not deteriorate further, and (iii) critical habitats are not degraded or lost forever. Therefore, ecosystem health monitoring in practice especially focuses on assessing the responses of the ecosystem to natural and human inputs. Biological indicators are often used for such type of health assessment that reflects community derived environmental values to infer overall ecosystem health. By evaluating the composition, diversity and condition/s of a plant or animal assemblage, bioscientists can determine or predict the overall 'health' of an ecosystem.

Three approaches are commonly used to assess health of an ecosystem:

(i) The identification of '**vital signs**' and '**symptoms**' that differentiate healthy ecosystems from sick ones i.e. the diagnosis of ecosystem health; (ii) The ability of an ecosystem to recover after an induced (artificially made) perturbation; (iii) The identification of '**risk factors**' that may threaten health i.e. to provide means to perceive a more integrated view of ecosystem behaviour under stress.

Symptoms or vital signs indicative of ecosystem distress are commonly known as 'ecosystem level distress syndrome.' These include (i) reduced primary productivity, (ii) loss of nutrients, (iii) reductions in species diversity or the loss of sensitive species, (iv) increased instability in component populations, (v) increased disease prevalence, (vi) change in the biotic size spectrum to favour

smaller opportunistic life forms e.g. 'r' species, (vii) increased circulation of contaminants, and (viii) the inability of an ecosystem to recover after a perturbation. It is recommended that while any of these symptoms may be sufficient to signal that an ecosystem is under stress, it is preferable to screen for all symptoms of ecosystem distress rather than to simply rely on one indicator as a measure of health. Similar to symptoms of ecological stress are **early warning indicators**. By monitoring the lower levels of ecosystem organization (e.g. at the population and organisms levels), one should be able to find indication of processes that may affect the behaviour of the whole. By identifying potential stressors, action may be taken to prevent potential disasters.

In a biological assessment, investigators evaluate the condition of one or more biological 'assemblages' (e.g. macro invertebrates, plants or fish). Since plants and animals assemblages reflect the cumulative effect of chemical, physical and biological disturbances to a habitat, bioscientists can use them much the same way as a doctor would use a thermometer and other instruments in human health diagnosis.

For the present investigation, a set of undergrowth indicators (Vide Inception Report, p. 21-22) for Sundarbans mangrove ecosystem, following the basic ecological principle, was envisaged. In order to test and validate their role and community functions, field studies at 24 sites (Table 1 and Map 1) representing a wide cross-section of the entire Sundarbans mangrove ecosystem were accomplished through two fifteen day's visits, the first of which was from 11-25 June, 2002 and the second was from 05-12 January and 27 January-02 February, 2003. Data regarding spatial distribution, abundance, density, association, habitat preference and stand formation, forest types and ecological/ environmental features were accumulated for various undergrowth species along with the initial set of indicators visualized earlier.

The Sundarbans Biodiversity Conservation Project (SBCP) provides an independent biodiversity conservation-monitoring component undertaken by IUCN, which has been assigned to the following tasks:

- i) to assess the existing current biodiversity and eco-functional health status of the Sundarbans;
- ii) to prepare an inventory of the major biodiversity components of the Sundarbans Reserve forest (SRF) at eco-zone, habitat and species level;
- iii) to build the capacity within the FD (Forest Department) for developing a viable and workable biodiversity health assessment system.

Keeping the targets of the above-mentioned tasks in mind, a thirty days field studies conducted in the various sites of the Sundarbans were completed during the rainy and dry winter seasons of 2002 and 2003 respectively. Data on important ecological features, species composition, interaction and function in each site were recorded. The effectiveness of initially identified targeted undergrowth indicator species was carefully observed and verified in order to screen out their inclusion or exclusion.

1.1. OBJECTIVES OF THE STUDY

The main objectives of this study are:

- a) to develop a suitable mechanism based on indicator undergrowth species for detection of significant changes in the biodiversity health status of the Sundarbans;
- b) which may act as an early warning system for the managers and planners of the Sundarbans;
- c) that can easily be used by the end-users and is cost-effective; and
- d) which may be practised at the field level by the personnel of FD.

1.2. Other objectives

1. Determination and making of a list of undergrowth species within the study area.
2. To determine indicator undergrowth species for different habitat types restricted communities and ultimately the health status of mangrove communities.
3. To indicate the unique patterns of composition, distribution, and diversity.
4. Determination of distribution patterns of communities, and their analysis in relation to exposure and inundation (salinity).
5. To note down the data regarding phenology and association.

CHAPTER-2**2. METHODOLOGY**

2.1. Sample Collection: Plant samples of different species, observed in the visited sites, were collected by Standard Quadrat Method (Braun-Blanquet, 1932; Raunkiaer, 1934). In almost all the sites, the standardized quadrats (Annexure 2) of 2m×2m size and in case of some sites with excessive growth of undergrowth species, quadrats of 1m×1m size were used for appropriate representation of undergrowth species for the purpose of analysis. The quadrat size was determined on the basis of species area curve (Braun-Blanquet, 1932).

The quadrats consisted of measuring thread and small (1m) straight poles. Four poles were fixed vertically and were encircled with the thread in such a way that it made a square shaped area (2m×2m or 1m×1m) on undergrowth vegetation. Representative plant samples were collected only from the square area of encircled poles.

2.2. Identification: All undergrowth species (Table 6 & Annexure 1) found in the visited sites of Sundarbans were identified by examining the collected plant samples by taxonomic expertise and through cross-checking with herbarium specimens preserved at BNH/DUH and matching the taxonomic description, keys or the photographs/illustrations in the relevant literatures, especially the recent Floras and Manuals.

- 2.3. Data collection:** The qualitative and quantitative data were collected only on the mature individuals of undergrowth indicator species, randomly selected from the quadrats. Specific data format (Annexure 2) was used for the collection of field data on each indicator species. The parameters were species specific (Annexure 3.1-3.9) and were measured with the help of centimeter scale and tape.
- 2.4. Verification of Indicator Species:** The indicativeness and effectiveness of initially identified indicator species for the assessment of biodiversity health status was verified on the basis of variation in their qualitative and quantitative characters as well as their ecological functions. Only the indicator species (Table 7 & Plate 23-29) showing the easily observable, countable and measurable variation in their qualitative and quantitative characters were screened, selected and ascertained finally for monitoring the biodiversity health status of Sundarbans ecosystem.
- 2.5. Phenological Study:** Phenological data were collected from the field observation and substantiated by other pertinent literature, baseline information, secondary sources like BNH or DUH in special format (Table 5).
- 2.6. Diversity Study:** Study of diversity status in each site was based on the quantitative data on undergrowth species, collected from at least six randomly taken quadrates on it's representative part and were recorded in specific format (Annexure-2). The collected data were analyzed by the calculation of Shannon-Weiner Diversity Index (Annexure-6a-28) as mentioned below and described by Kent & Coker (1992) for the assessment of diversity richness in order to corroborate the logical determination of biodiversity health status.

Shannon-Weiner Diversity Index (H') = $-\sum p_i \ln p_i$

where,

p_i = The proportion of individuals or the abundance of the

i th species expressed as a proportion of total cover,

\ln = Log base _{e}

2.7. Health Status Determination: The diversity status in various sites of freshwater and saline water zones of Sundarbans was evaluated by the comparison of the verified undergrowth indicator species (Table 7 & Plate 23-29) in terms of their qualitative and quantitative characters as well as by the presence or absence of few undergrowth indicator species. The data format for each verified indicator species was specific (Annexure 2.1-2.9) and was based on careful observation on certain qualitative and quantitative characters. The quantitative data were collected with the help of measuring tap and scale.

2.8. Geographical Location and Ecological Parameters: The specific geographical location of each site and certain ecological parameters were recorded in specific format (Annexure 4). The specific geographical location of each sampling spot was recorded from GPS readings. Soil pH and salinity of water were estimated by pH meter and salinity meter respectively. Soil and air temperature were recorded by centigrade thermometer.

CHAPTER-3

3. SITE DESCRIPTION

3.1. Site: JONGRA BEEL

This site was on plain land containing mostly moist-dry and rarely sandy soil. At this site, some small, open and depressed places were observed. During rainy season, these depressed places were observed with a thick layer (ca. 6") of clay and 2-3 ft of water level. But during the dry-winter season, these depressed areas



Plate-1. An area of Jongra Beel forest ecosystem.

were noted to be covered with thin layer of clay. The forest area of Jongra Beel (Map-1, Plate-1 & Table-1) was dominated by Sundri (*Heritiera fomes*) of about 40'-60', Poshur (*Xylocarpus mekongensis*) of 30'-45', Kankra (*Bruguiera gymnorrhiza*) of 25'-40', Bain (*Avicennia officinalis*) of 40'-50'

and Gewa (*Excoecaria agallocha*) of 30'-50' height. Almost all of the trees belonging to these species as well as the individuals of undergrowths were observed to be healthy.

3.2. Site: MIRGAMARI

At this site three sampling areas were surveyed. The sampling area -1 was a large open area of slightly depressed habitat covered by thick layer of clayey soil (ca. 6"-8" depth) not rich in humus. The sampling area-2 was comparatively smaller in

size at depressed habitat of 3-4 ft depth. During rainy season, this habitat was observed to be accumulating the rain and tidal water, as well as covered with very thick layer of clay (ca. up to 18"). During the winter season, this habitat was observed to be covered with comparatively less thick layer of clay (ca. 4"-6"). At this sampling area, both new and older populations of *Pseudoraphis* sp. were observed. The sampling area 3, adjacent to sampling area-2, was slightly elevated and composed of wet loamy soil rich in humus. The forest area of this site (Map-1, Plate-2 & Table-1) was observed to be dominated by healthy trees of Sundri (*Heritiera fomes*) of 30'-65' and followed by Kankra (*Bruguiera gymnorhiza*) of 20'-25', Poshur (*Xylocarpus mekongensis*) of 30'-50' and sometimes by Bain (*Avicennia officinalis*) of 40'-50' height. The individuals of Kankra were mostly in sapling stage, although some medium and large-sized trees were observed.



Plate-2. A part inside Mirgamari forest ecosystem.

3.3. Site: NEAR TERABEKA KHAL, SHARANKHOLA

At this site near Terabeka Khal, the sampling area (Map-1 & Table-1) was more or less homogeneous flat land of wet or dry sandy and hard loamy soil in both rainy and winter season. Rarely slightly depressed habitats beside or near the small shallow canals covered by thin layer (2-4 inch) of clay were observed mostly in rainy season. The forest of this sampling area was purely monotypic, composed of healthy, profusely branched and tall (ca. 60') trees of Sundri (*Heritiera fomes*). This might be the healthiest and richest monotypic forest of Sundri (*Heritiera fomes*) in the mangrove forest of Sundarbans.

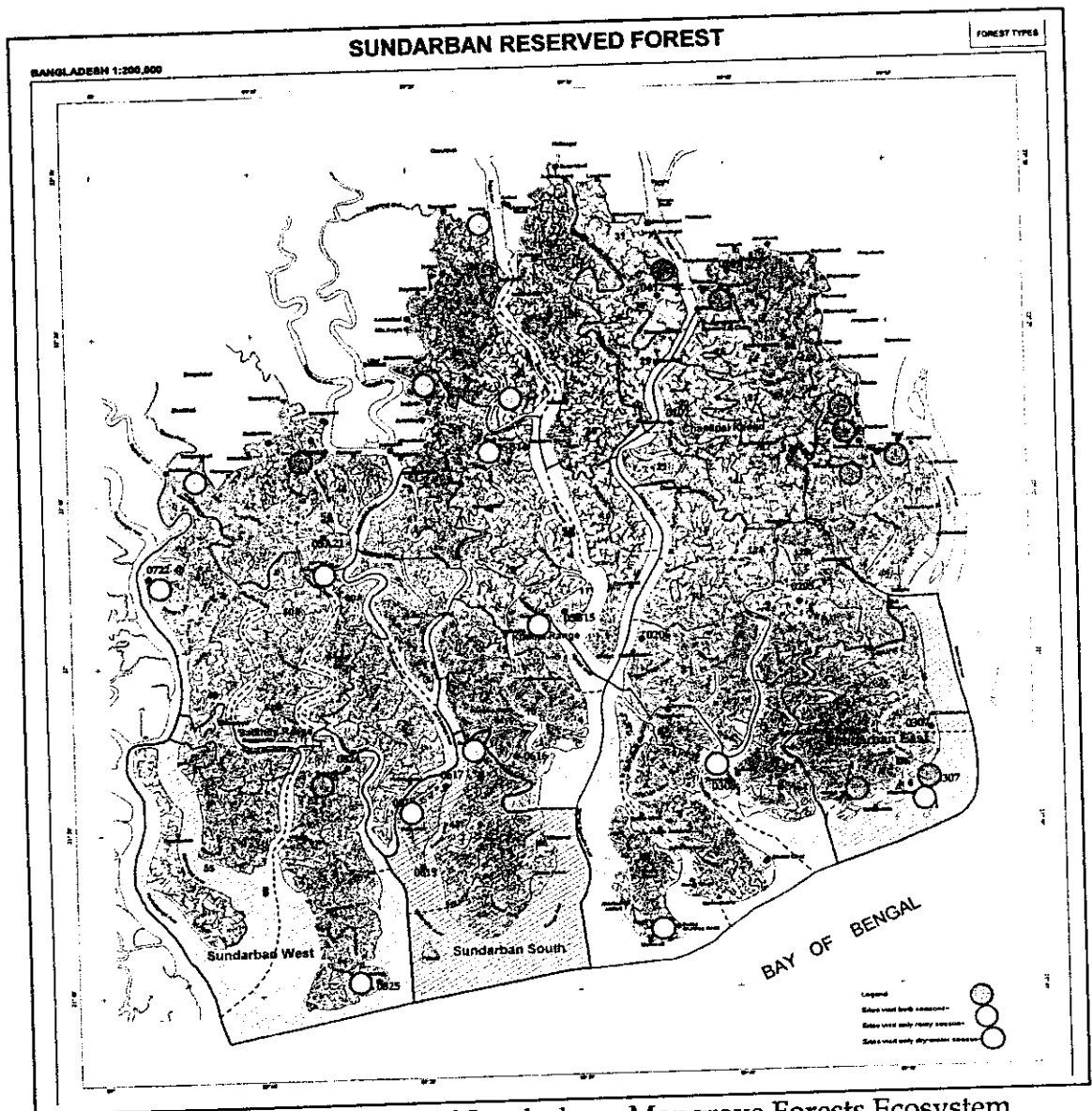
Table-1. Geographical location and ecological parameters of different visited sites of east and west Sundarbans.

Site	GPS Coordinates	Forest Type	Light (X10 lux)	Humidity (%)	Temperat (°C)	Water PH	Salinity (ppt.)
Jongra Beel	N22°22.198' E89°35.550'	Sundri Poshur Kankra	100-1200	36-37	29.2-29.5	6.8	4.6
Mirgamari	N 22°23.415' E 89°39.669'; N 22°23.15' E 89°40.06'	Sundri Kankra Poshur Bain	545-1185	40-45	24-28	8.5	5
Near Terabeka Khal	N 22°12'38.6" E 89°50'9.5"; N22°12'29.2" E 89°50'10.3"	Sundri	52-160	67-76	14.8-18	7.5	00
Panirghat	N22°13'44.2" E89°48'10.6" N22°13'45.5"; E 89°48'6.2"	Gewa Sundri	54-210	60	23.5-23.8	7.6	00
Near Sharankhola Range Office	N 22°12'25.2" E 89°48'28.9"	Gewa Sundri	22-72	45-61	24.4-25.2	7.7	00
South of Dhabribarani, Sharankhola	N 22°11'36.2" E 89°49'.00"	Gewa Sundri	100-1200	40-61	24.4-31.1	7.7	00
Patakata	N 21°59.174' E 89°42.503'; N21°59.08'9" E 89°42.41'3"	Sundri Gewa Goran	35-150	57-64	18.6-22.6		10
Tiarchar	N 21°51'6" E 89°38.46'6"	Kewra Gewa Goran	100-1200	76	14-28	7.6	15
Pakhhirchar	N 21°48.332' E 89°50.346'	Kewra	1736	66	19.3-20	7.8	7
Deemyer Char	N 21°51.21' E 89°51.154'; N 21°51.168' E 89°51.159'	Kewra Gewa Sundri	236-551	39-40	21-31.3	7.9	3
Kotka	N 21°51.263' E 89°47.257'; N 21°51.17'4" E 89°47'8"	Sundri Gewa Kewra	32-145	44-61	20.8-28.7	7.7	13
Dhanshiddher Char	N 22°13.052' E 89°35.102'	Sundri Poshur Kankra					16-18

(contd.)

Table-1. Geographical location and ecological parameters of different visited sites of east and west Sundarbans (contd.).

Site	GPS Coordinates	Forest Type	Light (X10 lux)	Humidity (%)	Temperat (°C)	Water PH	Salinity (ppt.)
KNM Collection Center	N 22°13.136' E 89°24.295'	Sundri Gewa					16-17
Kewrabunia/ Vojvojar Char	N22°017.246'E 89°025.495'	Kewra Sundri Gewa					16-17
Dobeki- Danokhali	N 22°07.507'; E 89°13.495'	Gewa- Goran- Poshur					20-21
Dubeki	N 22°005.401'; E 89°013.390'	Goran- Kewra- Poshur					20-22
Hodda	N 22°027.102'; E 89°035.014'	Kankra- Gewa- Sundri- Poshur					00
Kalagachia	N 22°13.124'; E 89°14.329'	Gewa- Goran- Poshur;		70-78	20.4-21		17
	22°13'36"; E89°14'21.3"	Gewa- Sundri- Goran- Poshur;		68-76	20.8-21.4		13-15
	N22°14'12"; E89°14'14.9"	Gewa- Goran- Sundri- Kewra;		61-64	21.6-22.3		13-14
Puspha Khathi	N 22°53.185' E 89°14.524'	Goran Gewa	740		20-25	5.1	22
Near Koikhali	N 22°09.030'; E 89°06.150'	KankraGe wa Sundri Poshur					20-21
East Part Of Raimangal River	N20°9'3" E 89°6'15.1"	Goran Gewa Sundri		57%	27	6.2	14-16
Dublar Char	N21°43'47", E89°36'15.2"	Gewa Kewra		50-51		7.5	20-21
Mandarbaria	N21°40'37.1"; E89°17'27.9"	Gewa Goran		64-88	22.9	6.8	20
Kalirchar (North)	N21°52'31.0"; E89°21'16.9"	Goran Gewa Kewra		68-73	21.3	5.9	20.2
Kalirchar (Middle)	N21°49'16.2"; E89°19'21.5"	Goran Gewa		50-52	30.2	5.8	20



Map-1. The visited sites of Sundarbans Mangrove Forests Ecosystem

3.4. Site: PANIRGHAT, SHARANKHOLA

In Panirghat, the sampling area (near the Camp Office) was beside the bank of a small river (Map-1, Plate-3 & Table-1) and characterized by an open, raised and plain habitat with slightly clayey soil in wet-rainy season and sandy-loamy hard soil in dry-winter season. The forest of this site was observed to be dominated by Gewa (*Excoecaria agallocha*) of 20'-30' and Sundri (*Heritiera fomes*) of 20'-40' height.

These were followed by more or less frequently distributed small-medium sized clumps of Goran (*Cerriops decandra*), especially inside the forest and large trees of Poshur (*Xylocarpus mekongensis*) and Bain (*Avicennia officinalis*) that were occasional and scattered among the densely distributed saplings and trees of Sundri and Gewa.



Plate-3. A part of Panirghat forest ecosystem.

3.5. Site: NEAR SHARANKHOLA RANGE OFFICE

This site was located near the bank of a small river opposite to the Sharonkhola Range Office (Map-1 & Table-1). In both seasons the sampling area was characterized by the elevated habitats of mostly hard loamy to less clayey soil and freshly sedimented, sandy or less clayey to thick clayey habitat. The forest of this site formed on the elevated habitats of mostly hard loamy and less clayey soil was observed to be dominated by frequently grown Gewa (*Excoecaria agallocha*) of 15'-20' and Sundri (*Heritiera fomes*) of 20'-25' height. These were followed by more or less frequently distributed small-medium sized clumps of Goran (*Cerriops decandra*), especially inside the forest and large trees of Poshur (*Xylocarpus mekongensis*) and Bain (*Avicennia officinalis*) that were rare among the densely distributed saplings and trees of Sundri and Gewa. The forest formed on slightly depressed and freshly sedimented to thick clayey habitat was clearly dominated by large individuals (ca. 30'-35' tall) of Golpata (*Nypa fruticans*).

3.6. Site: SOUTH OF DHABRIBARANI, SHARANKHOLA

The sampling areas of this site (Map-1, Plate-4 & Table-1) were characterized by the raised and plain habitats of wet sandy loamy to slightly clayey loamy soil. Inside the forest a large open and slightly depressed area of dry sandy loamy soil

dominated by old individuals of *Malia Ghash* (*Cyperus tagitiformis*) and irregularly interrupted by Tiger Fern (*Achrosticum aureum*) was observed. The forest of this site was mainly composed of densely grown small-medium sized healthy Sundri (*Heritiera fomes*) of 25'-40' and Gewa (*Excoecaria agallocha*) of 15'-25'

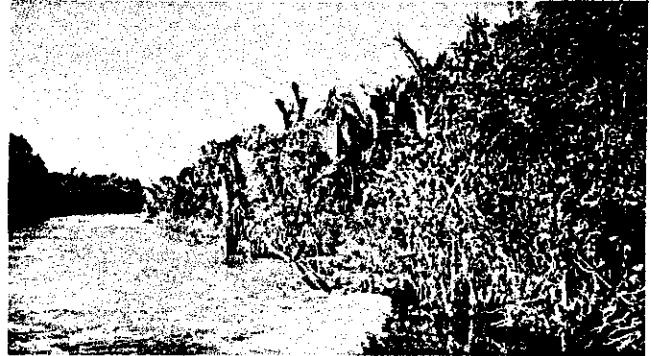


Plate-4. A part of forest ecosystem of South-Dhabrivarani.

height that were occasionally followed by Goran (*Ceriops decandra*) of 8'-10' height.

3.7. Site: PATAKATA

This site, visited only in winter season, was a transitional or an intermediate area between the saline and non-saline zone and represented the vegetation and habitats of both zones. This site was situated on the raised and elevated plain land near the Patakata Khal (Map-1 & Table-1). The habitats were of dry sandy loam and somewhat hard soil. The forest near the Khal was mostly dominated by the frequently grown Sundri (*Heritiera fomes*) of ca. 25'-30' and Gewa (*Excoecaria agallocha*) of ca. 15'-25' height and that of some distance away from the Khal was dominated by the frequently grown individuals of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) of ca. 20'-30' height and Goran (*Ceriops decandra*) of ca. 8' height.

3.8. Site: TIARCHAR

This site was visited only in winter season and observed to be a typical place for showing the successive formation of soil through heavy sedimentation and of new vegetation of mangrove plants (Map-1, Plate-5 & Table-1). The clear indication of heavy sedimentation was shown by the presence of mature trees of Kewra (*Sonneratia apetala*), the basal part (4'-5') of which was noted to be buried into new

soil. Most of this site was observed to be more or less uneven char-land of wet or dry and blackish-gray-ash colored soil. The soil at some depressed places was



Plate-5. An area inside Tiar Char.

seen to be covered by deep layer (ca. 4.5-6 cm) of slippery clay. Most of this area was noticed to be open and covered mostly by Dhanshi (*Porteresia coarctata*). The forest on the remaining parts were observed to be

dominated by the old trees of Kewra (*Sonneratia apetala*) of ca. 50'-65' height which were followed by Gewa (*Excoecaria agallocha*) of ca. 15, Goran (*Ceriops decandra*) of ca. 5'-7' and Nona Jhau (*Tamarix indica*) of ca. 6'-10' height. At certain places Goran (*Ceriops decandra*) and Nona Jhau (*Tamarix indica*) were seen to be densely grown between the individuals of Kewra and Gewa.

3.9. Site: PAKHHIRCHAR

This site was assumed to be a new char land surrounded by pure sandbar and visited only in winter season. The visited site of Pakhhirchar (Map-1, Plate-6 &

Table-1) was observed as newly formed uneven, depressed and raised char land. The habitats were of mostly pure sandy soil followed by sandy loam to wet or slightly clayey loam soil. A large part of this site was occupied by the pure sandbar, ca. 2-2.5 km long



Plate-6. An area inside Pakhir Char.

and 30-45m wide, and most of the remaining part was covered by Dhanshi (*Porteresia coarctata*). The pure cover of Dhanshi was followed by mixed area of

different species among which the only tree included Kewra (*Sonneratia apetala*) of ca. 20'-40' height. At some places, this area was occupied by nearly monotypic forest of Kewra in which the individuals of Poshur (*Xylocarpus mekongensis*) and Bain (*Avicennia officinalis*) of ca. 20' height were observed very rarely. At one large place surrounded by the trees of Kewra, nearly monotypic vegetation formed by *Kalia lata* (*Derris trifoliata*) was observed.

3.10. Site: DEEMYER CHAR

At this site, three sampling areas in both two seasons were investigated (Table-1). In both seasons, the habitats of this sampling area were more or less similar. The sampling area-1 was quite open and composed of wet, soft and sandy soil, frequently washed out by the sea waves and regularly by tidal water. This area was occupied mainly by the dense population of Dhanshi (*Porteresia coarctata*). The sampling area-2 was partially open elevated land of dry sandy soil which was mostly covered by Kash (*Saccharum spontaneum*) and Shon (*Imperata cylindrica*)/ Jhanjhoni (*Crotalaria juncea*) and the remaining part was more or less flat land of wet or slightly clayey loamy soil covered by the canopy of large trees (ca. 50'-60') of Kewra (*Sonneratia apetala*) and medium-sized trees (ca. 30'-45') of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*). The sampling area-3 near a small canal was found to be slightly depressed where the soil was covered by a thin layer (ca. 0.5 inch) of sediment followed by a thick layer (ca. 5 inch) of humus-rich black colored wet soil. At this sampling area, the large and healthy trees of Kewra (*Sonneratia apetala*) were observed, forming mostly a monotypic forest.

3.11. Site: KOTKA

At this site, four sampling areas were visited during rainy season whereas only two sampling areas during dry-winter season (Map-1, Plate-7 & Table-1). The sampling area-1 at the north side of Jamtala Khal and sampling area 2 at the south bank of Jamtala Khal west to the Jamtala Watch Tower were common in both

seasons. The sampling area-1 was on raised flat land of gray colored wet or dry loamy soil. The forest of this sampling area was observed to be dominated by Sundri (*Heritiera fomes*) of ca. 45'-60', Gewa (*Excoecaria agallocha*) ca. 30'-45' and Kewra (*Sonneratia apetala*) of ca. 50'-60' height. The sampling area-2 was more or less similar to that of the sampling area-1 along the north bank of Jamtala Khal, but was less mature and new with sandy or slightly clayey soil especially near the seashore. The forest was dominated by Sundri (*Heritiera fomes*) of ca. 45'-50', Gewa (*Excoecaria agallocha*) ca. 30'-40' and Kewra (*Sonneratia apetala*) of ca. 45'-60' height but that along the seashore was purely monotypic with healthy Kewra (*Sonneratia apetala*) of ca. 60' height. Near the Jamtala Watch Tower, there was an open area of elevated land with dry and sandy soil dominated by Tigerfern (*Achrosticum aureum*) and Kash (*Saccharum spontaneum*) and Shon (*Imperata cylindrical*) /Jhonjhoni (*Crotalaria juncea*). The sampling area-3, at the surrounding and behind the areas of Kotka Range Office, the forest was observed to be purely monotypic with large and healthy Kewra (*Sonneratia apetala*), the land was slightly elevated and the soil was dry and sandy loamy, somewhat like most of that of main land plains, and was followed by the nearly homogeneous one, covered with black and slippery layer of old humus. The sampling area-4 was at about 1.5 km north from the Kotka Forest Office, the forest of which was of mixed type, composed mainly of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) and scattered trees of Goran (*Ceriops decandra*). The land of the visited part of the forest was observed to



Plate-7. A part of Kewra (*Sonneratia apetala*) forest at Kotka

be elevated and the soil surface of which was found to be covered by a thin layer of sediment followed by a blackish humus rich layer.

3.12. Site: DHANSHIDDHER CHAR

Two sampling areas of this site were visited only during the rainy season. The sampling area-1 was beside the bank of Passur River (Map-1 & Table-1), the forest of which was nearly monotypic of old and large Sundri (*Heritiera fomes*) of up to ca. 100 ft high. The soil of this sampling area was sandy loamy and slightly clayey. At sampling area-2 inside the deep forest of large-sized Sundri (*Heritiera fomes*) with scattered ones of Poshur (*Xylocarpus mekongensis*) and Gewa (*Excoecaria agallocha*), the soil was quite clayey (ca. 4 inch thick).

3.13. Site: KMN COLLECTION CENTER

One sampling area of this site (Map-1 & Table-1) was visited during the rainy season. The visited forest of this site was mixed type, old, mature and composed mainly of Sundri (*Heritiera fomes*), Gewa (*Excoecaria agallocha*) and few scattered Pashur (*Xylocarpus mekongensis*). Many of the trees of Sundri (*Heritiera fomes*) and some of Gewa (*Excoecaria agallocha*) were seen to be affected by 'top-dying'. The soil of this area was sandy loamy, slightly sedimented and clayey and regularly washed out by the tidal water.

3.14. Site: KEWRABUNIA/VOJVOJAR CHAR

The forest areas of Vhojbhojar Char (Map-1 & Table-1), visited only in rainy season, were of two types, viz. monotypic forest of Kewra (*Sonneratia apetala*) and mixed forest of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*). The forest of Kewra (*Sonneratia apetala*) was observed to be pioneered by the second, but covers just an area of ca. 50-meter width. Scattered trees of Pashur (*Xylocarpus mekongensis*) were also observed. Soil of this forest area adjacent to river bank was

slippery, compactly clayey and covered by a thin layer of new sediment, followed by a blackish humus rich layer, but that of upper elevated part was less clayey and somewhat sandy loamy. The undergrowths of Kewra (*Sonneratia apetala*) forest were somewhat different from that of the mixed forest of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*).

3.15. Site: DOBEKI-DANOKHALI

This site is situated beside Kolagachhia Khal, Satkhira (Map-1 & Table-1). The forest of this site, visited during the rainy season, was mainly composed of profusely branched small bushes of Goran (*Ceriops decandra*) that were followed by Gewa (*Excoecaria agallocha*), represented by scattered individuals with the main trunk (up to ca. 30' tall) and without the main trunk i.e. consisting of new profuse branches sprouted from the base. The medium to large sized trees (up to ca. 50' tall) of Bain (*Avicennia officinalis*) and Pashur (*Xylocarpus mekongensis*) with profuse branching were also observed occasionally. The soil of both raised and plain places was sandy loamy, wet or slightly clayey and slippery.

3.16. Site: DUBEKI

This site is situated near Dubeki Patrol Post, Satkhira (Map-1 & Table-1). The forest of this area was composed mainly of profusely branched bushes of Goran (*Ceriops decandra*). Some large-sized mature trees of Kewra (*Sonneratia apetala*) were observed to be scattered in this area. Few small to medium-sized individuals of Gewa (*Excoecaria agallocha*), Bain (*Avicennia officinalis*), Sundri (*Heritiera fomes*) and Kakra (*Bruguiera gymnorhiza*) and large-sized trees of Pashur (*Xylocarpus mekongensis*) were observed to be scattered among the densely grown Goran (*Ceriops decandra*). The soil of this forest area was observed to be compact loamy to sandy -loamy and covered by a thin layer of slippery clay (1"-2" thick). The land of this area was observed to be elevated, but under the regular washing effect of tidal water.

3.17. Site: HODDA

This site is situated near Hodda Patrol Post, Khulna (Map-1 & Table-1). The forest of this area was found to be composed of frequently grown trees of Kakra (*Bruguiera gymnorrhiza*). Among the associated tree species of this forest, Sundri (*Heritiera fomes*) was found to be dominant which was followed by Pashur (*Xylocarpus mekongensis*), Kewra (*Sonneratia apetala*) and occasionally by Bain (*Avicennia officinalis*) and Gewa (*Excoecaria agallocha*). The frequently grown healthy and profusely branched trees of Kakra (*Bruguiera gymnorrhiza*) were found to form the second compact canopy under the thin first one of Kewra (*Sonneratia apetala*). The trees of all associated species were observed to be scattered. Excepting a few Sundri (*Heritiera fomes*), all other associated tree species were observed to be large, healthy and profusely branched. The land of this forest area was seen to be quite elevated, but under the effect of the tidal water flowing regularly. The soil near the canal, i.e. at the edge of forest was sandy loamy and non-clayey and that of inside the forest was compact loamy, covered by a thin layer of slippery clay.

3.18. Site: KALAGACHIA

At this site, three sampling areas were visited (Map-1 & Table-1). The sampling area-1, visited during rainy season, was situated at Kolagachhiathota (Burigualini). The forest area was dominated jointly by Goran (*Ceriops decandra*) and Gewa (*Excoecaria agallocha*). Scattered distribution of some old trees of Bain (*Avicennia officinalis*) and Pashur (*Xylocarpus mekongensis*) was also observed. The soil of this forest area was very compact, loamy or sandy loamy, sometimes slippery and poor in humus. Most of the places were plain, sometimes slightly elevated. The sampling area-2, situated near the sampling area-1 and sampling area-3, situated beside the Kewa-Khali Khal-were visited during winter season. The forest areas of sampling area-2 and sampling area-3 were mainly dominated by Gewa (*Excoecaria agallocha*) along with Goran (*Ceriops decandra*), Sundri

(*Heritiera fomes*), Kewra (*Sonneratia apetala*) and Poshur (*Xylocarpus mekongensis*) in different places. Most of the forest floor was observed as inundated frequently. There were many small canals and depressions inside the forest. Soils were clayey to clay-loam; and almost wet due to frequent inundation. Presence of Sundri (*Heritiera fomes*) plant was satisfactory. Other associated species viz. Kakra (*Bruguiera gymnorrhiza*), Poshur (*Xylocarpus mekongensis*), Bain (*Avicennia officinalis*), Kewra (*Sonneratia apetala*) and Amur (*Amoora cucullata*) were found to grow. A good number of Sundri saplings were also noticed. Many small canals and depressions were also observed.

3.19. Site: PUSHPA KATHI

This site is situated near Pushpakathi Patrol Post, Satkhira (Map-1 & Table-1). The forest of this area was mainly composed of densely grown bushes of Goran (*Ceriops decandra*). The associated trees were dominated by ill-developed, small-sized individuals of Gewa (*Excoecaria agallocha*). Few mature trees of Pashur (*Xylocarpus mekongensis*) and ill-developed small trees of Sundri (*Heritiera fomes*) were observed to be scattered. Other associated species were Amur (*Amoora cucullata*), Dhundul (*Xylocarpus granatum*), Kholshi (*Aegiceras corniculata*), Kakra (*Bruguiera gymnorrhiza*), Bain (*Avicennia officinalis*)s and Poshur (*Xylocarpus mekongensis*). Wood-decay was noticed in the tree trunks. Most of the undergrowth association was found to occur along with the bank side in the periphery of the forest. The area of this forest was observed to be elevated and composed of compact sandy-loamy soil with a thin layer of slippery clay during both rainy and winter season that might be washed out repeatedly by the tidal water.

3.20. Site: NEAR KOIKHALI

The forest of this area (Map-1 & Table-1), visited during rainy season, was mainly composed of Goran (*Ceriops decandra*). The associated tree species were Gewa

(*Excoecaria agallocha*) and Sundri (*Heritiera fomes*). Few scattered individuals of Pashur (*Xylocarpus mekongensis*) and Bain (*Avicennia officinalis*) were also observed. All of the trees of Gewa (*Excoecaria agallocha*) were small, without profuse branching, inadequately mature and with slender trunk. The soil of this forest area was very compact, loamy or sandy loamy and poor in humus. Most of the places were more or less plain, sometimes slightly elevated.

3.21. Site: EAST PART OF RAIMANGAL RIVER

The river 'Raimangal' divides the Sundarban of Bangladesh and Indian part (Map-1, Plate-8 & Table-1). This forest is situated in the east part of the river and was visited during winter season.

It is a Goran (*Ceriops decandra*) dominated forest in association with good number of Gewa (*Excoecaria agallocha*) and Sundri (*Heritiera fomes*). The habitats were observed to be frequently inundated and soils were mostly clayey that



Plate-8. A part of the forest ecosystem near the east part of Raimangal River.

might be due to the flowing of tidal water. Other associated species viz. Bain (*Avicennia officinalis*), Kakra (*Bruguiera gymnorrhiza*), Poshur (*Xylocarpus mekongensis*) and Amur (*Amoora cucullata*) were found to grow scatteredly.

3.22. Site: DUBLAR CHAR

This site, visited during dry-winter season, was dominated by Kewra forest along the margin and Gewa-Goran in inside (Map-1 & Table-1). That means two types of vegetation were observed viz. monotypic Kewra (*Sonneratia apetala*) and mixed type Gewa (*Excoecaria agallocha*) with Goran (*Ceriops decandra*). Few unhealthy

Sundri (*Heritiera fomes*) were also found to grow scatteredly. Other associated species included Kakra (*Bruguiera gymnorrhiza*), Kirpa (*Corallia bracheata*), Poshur (*Xylocarpus mekongensis*), Kholshi (*Aegiceras corniculata*) and some other grasses and sedges. Soil of this site was dry, sandy to sandy-loamy in riverside and clayey inside the forest. Interference and encroachment due to the presence of seasonal fishermen's settlement were notable in this forest.

3.23. Site: MANDARBARIA

This site belonging to Satkhira range (Map-1 & Table-1) was visited during winter season. It was a Gewa (*Excoecaria agallocha*) dominated forest with understorey Goran (*Ceriops decandra*). Some trees of Sundri (*Heritiera fomes*) plants were scatteredly distributed. In extreme southern part of the forest some big-sized Kewra (*Sonneratia apetala*) were found to grow. Other associated tree species, that were found to grow there in small number, were Kirpa (*Corallia bracheata*), Bain (*Avicennia officinalis*), Dhundul (*Xylocarpus granatum*), and big sized Kewra (*Sonneratia apetala*). In addition, some other undergrowth species, viz. Kontikari (*Solanum xanthocarpum*), Moinakanta (*Xeromphis spinosa*), Jhanjhari (*Crotalaria* sp.) and Sun-grass were also observed. Soil of this site was sandy-loamy near seashore, but inside the forest was mainly clayey.

3.24. Site: KALIRCHAR

At Kalirchar (Map-1 & Table-1), two sampling areas were visited during the winter season. The sampling area-1 was in the north part of this char land. Kalirchar-North was basically a frequently inundated habitat with very thin vegetation. It was dominated by Kewra (*Sonneratia apetala*) with understorey of Goran (*Ceriops decandra*). Denser population of Goran (*Ceriops decandra*) was found to occur along with the bank-side but in inside the forest, thinly populated Kewra (*Sonneratia apetala*) was recorded. Bain (*Avicennia officinalis*) was observed as the associated forest tree. This forest was separated in east-west into two parts

by a small channel. There was a distinct difference in elevation of the northern and southern part of the forest. Southern part was at the higher elevation of 2'-3' in respect to that of northern one, which was supposed to be an exceptional and of seldom occurrence in mangrove ecosystem. Remarkably good mangrove association was observed in the northern part, while it was very thin in the southern part. In northern part, the dominating Goran (*Ceriops decandra*) individuals were of very good growth along with Gewa (*Excoecaria agallocha*) saplings. In this part, the scattered individuals of Poshur (*Xylocarpus mekongensis*), Nona-Jhau (*Tamarix indica*) and big sized Sundri (*Heritiera fomes*) were also observed. In southern part, the forest was dominated by healthy Kewra (*Sonneratia apetala*). As the associated species, Amur (*Amoora cucullata*), Bain (*Avicennia officinalis*), Moinakanta, and some of the grasses and sedges were found to grow in this part, but no Sundri (*Heritiera fomes*) was observed. In both northern and southern parts of this sampling area, soil was predominantly deeply clayey.

The sampling area-2 was at the middle of Kalirchar. This area was mainly of Goran (*Ceriops decandra*) dominated forest along with Gewa (*Excoecaria agallocha*) and Bain (*Avicennia officinalis*). Some big-sized Kewra (*Sonneratia apetala*) trees were also observed. Other associated species were Bain (*Avicennia officinalis*), Kholshi (*Aegiceras corniculata*) and Sundri (*Heritiera fomes*). Inside the forest, there was a large open area, covered mostly by grasses. Soil of this sampling area was mostly clayey.

CHAPTER-4**4. OBSERVATION**

The undergrowths of different sites of east and west Sundarbans visited during rainy and/or dry winter season were observed carefully in order to screen the indicator species and to justify their credibility for the assessment of biodiversity health status. The site-wise observation on the status of undergrowth species has been mentioned below and their important functions and indication are evaluated in the discussion section.

4.1. Site: JONGRA BEEL

In the visited area of Jongra Beel, the undergrowth species were found to be composed mainly of Malia Ghash (*Cyperus spp.*), *Pseudoraphis sp.*, Hargoza (*Acanthus ilicifolius*), Keya (*Pandanus foetidus*), Bhola (*Hibiscus tiliaceus*), Hental (*Phoenix paludosa*), *Clerodendrum sp.* and Kalia Lata (*Derris trifoliata*) in both rainy and winter seasons. Malia Ghash (*Cyperus spp.*) was found to be in scattered clumps, mixed and homogeneous population mixed with that of *Pseudoraphis sp.* in open and depressed sampling sites that were under water of 1'-3' depths in rainy season. Individuals of Malia (*Cyperus spp.*) and *Pseudoraphis sp.* were absent at two of the same open, depressed sampling areas that might be due to pollution, since these were found to emit foul odour from their water. Keya (*Pandanus foetidus*) and Nona Jhau (*Tamarix indica*) were found as associate species at the edge of the depressed sampling areas occupied by Malia Ghash (*Cyperus spp.*) and *Pseudoraphis sp.* Hargoza (*Acanthus ilicifolius*) and Keya (*Pandanus foetidus*) were found in scattered dense populations (Plate-1) forming open mixed cover along with the scattered seedlings and mature individuals of Bhola (*Hibiscus tiliaceus*), Kalia Lata (*Derris trifoliata*) and *Clerodendrum sp.* etc. on the raised edge

of a small canal. These species were also found as scattered individuals and clumps on the elevated areas near the small canal. In the visited sites of Jongra Beel, the mature individuals of Bhola (*Hibiscus tiliaceus*), Hental (*Phoenix paludosa*) were found as scattered clumped undergrowths of Sundri (*Heritiera fomes*), Bain (*Avicennia officinalis*) and Pashur (*Xylocarpus mekongensis*), but not in good number. The seedlings and saplings of tree species were mainly of Sundri (*Heritiera fomes*) that were observed to be scattered. The broad leaves



Plate-9. Rich diversity in fresh water mangrove ecosystem (Jongra Beel).

of Bhola (*Hibiscus tiliaceus*) were not found to form a second canopy at this site. The population of Bhola (*Hibiscus tiliaceus*) was very dense along the adjacent areas and upper bank of a small canal. Tiger fern (*Achrosticum aureum*) was found in scattered clumps in both depressed and raised sampling areas. The individuals of another pteridophyte Dhekia Lata (*Stenoclaena palustris*) were found to be growing extensively and vigorously along the stem of a few tree species from the base up to the apex and branches, especially on Sundri (*Heritiera fomes*) that might be detrimental to the normal growth of these trees. Abetee (*Flagellaria indica*), Gila Lata (*Entada pursaetha*) and Angoor Lata (*Vitis sp.*) were found as associate species along with the other undergrowth species of raised sampling areas. At this fresh water site of Sunderbans, the overall biodiversity health status as well as the ecosystem was appeared as very good both in terms of richness, frequency and growth performances or biomass formation of different species (Plate-9). A pronounced successional trend for the replacement of Bain (*Avicennia officinalis*) and Pashur (*Xylocarpus mekongensis*) by Sundri (*Heritiera fomes*) was assumed to be continuing. Sometimes it was observed that the dense growth of undergrowths,

especially of Keya (*Pandanus foetidus*), were remarkably disturbed due to the encroachment and destruction by visiting poor people. Natural destruction of biomass was observed to be restricted to Bain (*Avicennia officinalis*) and Pashur (*Xylocarpus mekongensis*) by different causal agents, such as insects, birds, woodborers and the wood-decaying microorganisms.

4.2. Site: MIRGAMARI

In the visited sampling areas of Mirgamari, the undergrowth species were found to be composed mainly of Malia Ghash (*Cyperus* spp.), *Pseudoraphis* sp., Nal Khagra (*Phragmites karka*), (Plate-10) Keya (*Pandanus foetidus*), Hargoza (*Acanthus ilicifolius*), Bhola (*Hibiscus tiliaceous*) and Hental (*Phoenix paludosa*) in both rainy and winter seasons.

At sampling area-1, Malia Ghash (*Cyperus* spp.) was found in dense population composed of healthier individuals than in Jongra Beel. Many individuals of *Pseudoraphis* sp. were found as mixed with those of Malia Ghash (*Cyperus* spp.). Adjacent to the population of Malia Ghash (*Cyperus* spp.) and *Pseudoraphis* sp., scattered individuals and small population of Nal Khagra (*Phragmites karka*) and some seedlings of Kakra (*Bruguiera gymnorhiza*) were found in slightly raised habitat. At sampling area-2, the



Plate-10. Undergrowths at a margin of Mirgamari forest

populations of Malia Ghash (*Cyperus* spp.) and *Pseudoraphis* sp. were comparatively smaller on a more depressed habitat (3-4ft in depth) accumulating rain and tidal water covered with thicker layer (up to 18") of clay in the rainy

season. At this sampling area, both new and older populations of *Pseudoraphis* sp. were observed during rainy and dry winter season. Adjacent to sampling area-2, the populations of these two species were absent on an open depressed habitat covered with thin layer of clay and humus. This observation is somewhat similar to that in Jongra Beel. In sampling area-2, clumps of individuals of Nal Khagra (*Phragmites karka*), Hargoza (*Acanthus ilicifolius*), and Keya (*Pandanus foetidus*) were found as first secondary plants at the non-raised edge of the depressed habitat. Near the depressed habitat, fresh formation of both dense and scattered seedlings and saplings of Kakra (*Bruguiera gymnorhiza*) were observed between the healthy trees of the same species, but no undergrowth was found. The individuals of Kakra (*Bruguiera gymnorhiza*) were observed to be followed by some seedlings of Sundri (*Heritiera fomes*).

At sampling area 3, Bhola (*Hibiscus tiliaceous*) was observed in clumps under the canopies of Sundri (*Heritiera fomes*), Kakra (*Bruguiera gymnorhiza*) and Possur (*Xylocarpus mekongensis*). The population of Bhola (*Hibiscus tiliaceous*) was found to form the second canopy, allowing only the growth of some scattered individuals of Keya (*Pandanus foetidus*). Some clumps of Hental (*Phoenix paludosa*), composed of retardedly grown slender, and stunted individuals were observed at the raised or elevated habitats of less sedimented or clayey soil.

At sampling area 3, very poor diversity of undergrowth was observed under the canopy of old trees of Sundri (*Heritiera fomes*) providing enough shade over their underlying areas. But the diversity of healthy undergrowths was observed to be comparatively richer at less shady or open situations between the canopies. In the visited sampling areas of Mirgamari, the populations of Malia Ghash (*Cyperus* spp.), Bhola (*Hibiscus tiliaceous*), *Pseudoraphis* sp. and Nal Khagra (*Phragmites karka*) were more dense and larger than in Jongra Beel (Plate-10). Beside this, the density of seedlings of Sundri (*Heritiera fomes*) and Kakra (*Bruguiera gymnorhiza*) were more higher than in Jongra Beel. The diversity of associate species was assumed to be comparatively richer at this site than in Jongra Beel. At sampling area-3, the

scattered individuals or clumps of Keya (*Pandanus foetidus*) were found to indicate similar habit feature of Bhola (*Hibiscus tiliaceus*).

The leaves of Keya (*Pandanus foetidus*) found at Mirgamari was recorded to be rather longer, whereas the individuals of Bhola (*Hibiscus tiliaceus*) were noticed to be less branched than that of Jongra Beel. The frequency and length of Hental (*Phoenix paludosa*) found inside the forest was noticeably lower than that in Jongra Beel, although the individuals of this species growing on the bank of the canal appeared to be similar to that growing at the same places in Jongra Beel.

The health status of diversity observed in the sampling areas of Mirgamari was assumed to be nearly similar to that in Jongra Beel in terms of species richness, health status, successional trends and small-scale anthropogenic and natural destruction of biomass, although the species composition was slightly different.

4.3. Site: NEAR TERABEKA KHAL, SHARANKHOLA

The more commonly found undergrowth species of this sampling area were Shingra (*Cynometra ramiflora*), Kalia Lata (*Derris trifoliata*), Hental (*Phoenix paludosa*), Bhola (*Hibiscus tiliaceus*) and Angoor Lata (*Vitis* sp.) in both rainy and winter seasons, but the individuals of the first two were more frequent than that of the latter ones. Shingra (*Cynometra ramiflora*) were found to grow all over the monotypic forest of the visited area. Most of the plants of Hental (*Phoenix paludosa*) were found either as small seedlings (15-45 cm) or as very stunted mature individuals. At one small place inside the forest, Bhola (*Hibiscus tiliaceus*) was found to form nearly monotypic dense vegetation. Individuals of Kalia Lata (*Derris trifoliata*) were rarely observed to spread over Sundri (*Heritiera fomes*) trees. The seedlings of Sundri were found in good number, especially under the canopy of its old large trees, but their growth was not observed to be inhibited by the aggressive growth of Kalia Lata (*Derris trifoliata*). The less commonly found species were Hargoza (*Acanthus ilicifolius*), Keya (*Pandanus foetidus*), *Pandanus* sp.

and Angoor Lata (*Vitis* sp.). At one place near the margin of the forest very healthy and tall (1.5-2.1 m) individuals of Keya (*Pandanus foetidus*) were noticed. At another place near a small canal inside the forest, the individuals of *Pandanus* sp. were found to grow densely. The individuals of Assam Lata (*Mikania cordata*) were found to form a covering over the individuals of other undergrowth at few open places between the canopies of Sundri (*Heritiera fomes*). As in some other visited sites, the undergrowths of this sampling area were found to be richer in diversity at the open places than under the canopies. Under the canopies of mature trees, the diversity of undergrowths was recorded to be mostly very poor and dominated by the seedlings of the same.

At this site, although the biomass composed of apparently very healthy Sundri (*Heritiera fomes*) trees, which might be the healthiest among the Sundri (*Heritiera fomes*) dominated forests and the biodiversity health status was assumed to be quite good, but the total plant diversity was not so good in term of species richness. The successional trends were not clear at this site. Natural destruction of biomass by different causal agents, such as insects, birds, woodborers and the wood-decaying microorganisms was not noticeable.

4.4. Site: PANIRGHAT, SHARANKHOLA

At the visited sampling area beside the bank of a small river of this site (near the Camp Office), few species like Horma Ghash (*Hemarthrea* sp.), *Echinochloa crusgalli* and *Scirpus* sp. were observed in mixed dense populations with that of Malia Ghash (*Cyperus* spp.) on open raised and shallowly sloping habitat composed of less clayey sandy soil. In addition to these, other species like Kash (*Saccharum spontaneum*), *Eriocaulon* sp., Hogla (*Typha aunguastata*) and Shola (*Aeschynomene* sp.) were also noticed to form dense mixed populations following the pioneer homogeneous population of Dhanshi (*Porteresia coarctata*). The mixed populations of the above mentioned species were found to be followed by the nearly homogeneous dense population of Nal Khagra (*Phragmites karka*) on open, more

raised and less clayey habitat near the river bank, as in some areas beside the bank of the canal at Jongra Beel. The marginal populations of Nal Khagra (*Phragmites karka*) were found to be suppressed and gradually checked by the dense populations of mature and healthy Bhola (*Hibiscus tiliaceous*). Under the dense population of Bhola (*Hibiscus tiliaceous*) no individuals of undergrowth species were found to grow. The populations of these species were found to be gradually replaced by that of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*).



Plate-11. Undergrowths in inside of the Sundri-Gewa dominated forest at Panirghat.

As in sampling area-3 of Mirgamari, very poor diversity of undergrowth was noticed in the inside of the forests (Plate-11), especially under the canopies of profusely branched old trees of Sundri (*Heritiera fomes*), Gewa (*Excoecaria agallocha*) and Possur

(*Xylocarpus mekongensis*) forming enough shade over their underlying areas. In contrast, rich diversity of undergrowths including the dense growth of seedlings of Sundri (*Heritiera fomes*), sometimes of Gewa (*Excoecaria agallocha*) were observed under the canopy of medium-sized trees of Sundri (*Heritiera fomes*) providing comparatively less shade over the underlying areas of the elevated places of the sampling areas of Mirgamari. At this site, species like Kalia Lata (*Derris trifoliata*), Angoor Lata (*Vitis* sp.) and Shingra (*Cynometra ramiflora*) were found in good number inside the forest on the elevated sites of mostly loamy soil, as in that of Mirgamari.

At this fresh water site, the overall biodiversity health appeared to be very good at the edges of forests in terms of species richness, health status and regeneration

and moderately good inside mostly in terms of very high frequency of few less healthy species. A pronounced successional trend for the replacement of Bain (*Avicennia officinalis*) and Pashur (*Xylocarpus mekongensis*) by Sundri (*Heritiera fomes*), Gewa (*Excoecaria agallocha*) and Goran (*Ceriops decandra*) was observed. Sometimes instances of anthropogenic activities inside the forest was observed. Very small-scale natural destruction of biomass was noticed to be restricted mostly to Bain (*Avicennia officinalis*) and Pashur (*Xylocarpus mekongensis*) by different causal agents, such as insects, birds, woodborers and the wood-decaying microorganisms.

4.5. Site: NEAR SHARONKHOLA NANGE OFFICE

At this site, undergrowths were mainly represented by healthy Malia Ghash (*Cyperus* spp.), Hogla (*Typha aungustata*), Shola (*Aeschynomene* sp.) Dhanshi (*Porteresia coarctata*) forming very dense vegetation on the same type of habitat beside the bank of the river at Panirghat. The mixed populations of these species were found to be followed by the nearly homogeneous dense population of Nal Khagra (*Phragmites karka*) on open, more raised and less clayey habitat near the river bank, as in Panirghat and at some areas beside the bank of the canal at Jongra Beel. The individuals of Golpata (*Nypa fruticans*) observed following the above-mentioned vegetation were assumed to be the largest (ca. 30'-35' tall) and healthiest among all the visited sites of east and west Sundarbans. The types and status of undergrowths inside the forests of Gewa (*Excoecaria agallocha*), Sundri (*Heritiera fomes*) and Goran (*Ceriops decandra*) in the association of Poshur (*Xylocarpus mekongensis*) and Bain (*Avicennia officinalis*) were more or less similar to that in the deep forests at Panirghat and South Dhabribarani of Sharonkhola.

The overall biodiversity health of this fresh water site appeared to be very 'good' at the edges of forests in terms of species richness, health status and regeneration and 'moderately good' inside mostly in terms of high frequency of few less healthy species. A pronounced successional trend for the replacement of Bain

(*Avicennia officinalis*) and Pashur (*Xylocarpus mekongensis*) by Sundri (*Heritiera fomes*), Gewa (*Excoecaria agallocha*) and Goran (*Ceriops decandra*) was observed. Sometimes instances of anthropogenic activities inside the forest was observed. Very small-scale natural destruction of biomass was appeared as restricted mostly to Bain (*Avicennia officinalis*) and Pashur (*Xylocarpus mekongensis*) by different causal agents, such as insects, birds, woodborers and the wood-decaying microorganisms.

4.6. Site: SOUTH OF DHABRIBARANI, SHARANKHOLA

At this site the undergrowth species Kalia Lata (*Derris trifoliata*), Hental (*Phoenix paludosa*), Chhitki Lata (*Phyllanthus reticulatus*), Shingra (*Cynometra ramiflora*) and Angoor Lata (*Vitis* sp.) were found to be more common in both seasons. Among



Plate-12. Undergrowths at the margin of Sundri-Gewa dominated forest at South Dhabrivarani.

these species, Hental (*Phoenix paludosa*) was observed as scattered individuals of different lengths (0.6-1.5 m). Hargoza (*Acanthus ilicifolius*) and Bhola (*Hibiscus tiliaceus*) were rare at this sampling area, although some clumps of their individuals were

observed along the opposite bank of a canal in front of this sampling area. Some healthy individuals of Keya (*Pandanus foetidus*) were found at slightly sedimented spot. Some associated species like Chhitki Lata (*Phyllanthus reticulatus*), Shingra (*Cynometra ramiflora*) and Angoor Lata (*Vitis* sp.) were found in good number. At the heavily sedimented or clayey slope of a small canal, the dense population of

Dhanshi (*Porteresia coarctata*) was found to be mixed with that of Hogla (*Typha aungustata*). The similar phenomenon was observed at the sampling area of Panirghat. At this sampling area, the seedlings of Sundri (*Heritiera fomes*) and Goran (*Ceriops decandra*) were found in good number under the canopy of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*), although those of Gewa were rare.

The plant diversity of this site seemed to be more or less similar in nature and richness as in the visited site of Panirghat and near Sharankhola Range Office. The overall biodiversity health of this fresh water site appeared to be good at the edges (Plate-12) as well as in the inside of the forests, mostly in terms of frequency of healthy individuals and regeneration of most of the species. The successional trends at this site were assumed as difficult to understand but the introduction of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) in association of *Ceriops decandra* (Goran) was observed to be continuing. Instances of anthropogenic activities inside the forest and natural destruction of biomass by different causal agents, such as insects, birds, woodborers and the wood-decaying microorganisms were not remarkable.

4.7. Site: PATAKATA

The undergrowths of this site were observed to be dominated by Shingra (*Cynometra ramiflora*), Kalia Lata (*Derris trifoliata*), Keya (*Pandanus foetidus*) and Hental (*Phoenix paludosa*). The associate undergrowths included Angoor Lata (*Vitis* sp.), Golpata (*Nypa fruticans*), Hargoza (*Acanthus ilicifolius*), Amoor (*Amoora cuculata*), Moina Kata and Karanja (*Poungamia pinnata*). Except Kalia Lata (*Derris trifoliata*), all of these undergrowth species were noticed to be restricted in distribution within 7.5m towards the forest. Individuals of Keya (*Pandanus foetidus*) and Hental (*Phoenix paludosa*) were observed to grow only near the bank of the canal. Individuals of Shingra (*Cynometra ramiflora*) and Keya (*Pandanus foetidus*) were observed to be healthier and that of Hental (*Phoenix paludosa*) were

taller, slender or ill-developed. The overall plant diversity of this marginal area was evaluated to be comparatively richer and healthier than in the deeper areas of the forest. Inside the deeper areas of the forest, the undergrowths were represented only by *Kalia Lata* (*Derris trifoliata*) that might be due to the Goran-loving type of habitat composed of hard, dry and sandy-loam soil.

The overall biodiversity health of this site located in the transitional zone of fresh and saline water areas appeared to be moderately good at the edges both in terms of species richness as well as health of the individuals and in the inside of the forest in terms of frequency of healthy individuals of Goran (*Ceriops decandra*). A pronounced successional introduction of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) was also noticeable. Instances of anthropogenic activities and natural destruction of biomass by different causal agents, such as insects, birds, woodborers and the wood-decaying microorganisms were not remarkable.

4.8. Site: TIAR CHAR

The undergrowths of this site were found to be composed of Dhanshi (*Porteresia coarctata*), Nona Jhau (*Tamarix indica*) and Hargoza (*Acanthus ilicifolius*) in winter season (Plate-13). Dhanshi (*Porteresia coarctata*) occurred as a continuous mat-cover of different thickness or density, surrounding most of the marginal open areas of the entire island. Healthy individuals of Hargoza (*Acanthus ilicifolius*) were observed in small patches mostly beside the small canals and sometimes in open places inside the forest. At certain



Plate-13. Poor diversity in saline water mangrove ecosystem (Tear Char)

places, Nona Jhau (*Tamarix indica*) was observed as densely grown (Plate-5 and Plate-13) between the individuals of Keora and Gewa. Kalia Lata (*Derris trifoliata*), Amoor (*Amoora cuculata*) and Moina Kanta were observed to be occasional and mostly in seedling stage. A single clump of Hental (*Phoenix paludosa*) was observed at one place near a small canal. The plant diversity at this site of high saline zone was assumed to be unhealthy, in terms of richness, frequency, biomass and regeneration of species (Plate-13), but the ecosystem was assumed as promising. A successional replacement of old and mature Keora (*Sonneratia apetala*) and initiation of Gewa (*Excoecaria agallocha*) and Goran (*Cerriops decandra*) were apparent. Instances of anthropogenic activities inside the forest and natural destruction of biomass by different causal agents, such as insects, birds, woodborers and the wood-decaying microorganisms and other animals were not remarkable.

4.9. Site: PAKHHIR CHAR

The undergrowths of this site were observed to be composed mostly of Dhanshi (*Porteresia coarctata*) and Kalia Lata (*Derris trifoliata*) in winter season, which were occasionally followed by Hargoza (*Acanthus ilicifolius*), Bhola (*Hibiscus tiliaceous*) and Angoor Lata (*Vitis* sp.) and rarely by Kholshi (*Aegiceras corniculata*), Golpata (*Nypa fruticans*) and Bhat Kathi (*Bruguiera parviflora*). Dhanshi (*Porteresia coarctata*) were observed to form a dense cover, mostly monotypic in composition over a large area following the sand bar and



Plate-14. Hargoza (*Acanthus ilicifolius*) in the population of Dhanshi (*Porteresia coarctata*)

occasionally associated with ill-developed and stunted individuals of Hargoza (*Acanthus ilicifolius*) (Plate-14) and this type of dense cover indicated the same behaviour as in other sites. The dense cover of Dhanshi (*Porteresia coarctata*) was also observed exceptionally in the open areas within the monotypic forest of Keora (*Sonneratia apetala*) and was associated with the occasional distribution of Hargoza (*Acanthus ilicifolius*) and rarely distributed Kholshi (*Aegiceras corniculata*) and Bhat Kathi (*Bruguiera parviflora*). The undergrowths in and near Keora forest were observed to be composed mostly of healthy individuals of Kalia Lata (*Derris trifoliata*) and Hargoza (*Acanthus ilicifolius*). Kalia Lata (*Derris trifoliata*) were observed to form a very dense cover on an area of about 0.5 km length and 12-24m width and assumed to check the extension of Keora forest. This phenomenon was noticed for the first time in mangrove forest of Sundernban. The individuals of Hargoza (*Acanthus ilicifolius*) inside the Keora forest were found to be very tall and healthy.

At this low saline site of Sundarbans, the overall biodiversity health as well as the ecosystem appeared to be good, both in terms of richness, frequency, health status and regeneration of different species. A distinct successional trend for the large-scale replacement of Dhanshi (*Porteresia coarctata*) mostly by Keora (*Sonneratia apetala*), occasionally by the undergrowths like Hargoza (*Acanthus ilicifolius*) and Kalia Lata (*Derris trifoliata*) (Plate-6) and rarely by Poshur (*Xylocarpus mekongensis*) and Bain (*Avicennia officinalis*) was also observed. Introduction of a good number of plain land mesophytic species was also noticeable. Anthropogenic and natural destruction of biomass was not remarkable.

4.10. Site: DEEMYER CHAR

The north and western edge of this site composed of wet, soft and sandy soil frequently washed out by the sea waves and regularly by tidal water was occupied by the dense and large populations of Dhanshi (*Porteresia coarctata*) in both rainy and winter seasons. At Deemyer Char, although Dhanshi (*Porteresia*

coarctata) was observed to be the pioneer species, but a large area (ca. 60 m wide and 1.5 km long) encircling the central forest of Keora (*Sonneratia apetala*) was found to be dominated in both seasons by the species that are commonly found at many areas of the main land plains. These species are *Saccharum spontaneum*, *Imperata cylindrica*, *Crotalaria juncea*, *Hemarthria* sp., *Eleusine indica*, *Eragrostis* sp., *Cuscuta reflexa*, *Phyllanthus niruri*, *Ficus* sp., Kath Badam (*Terminalia catappa*), *Paspalum* sp., *Dioscorea* sp., *Atylosia* sp., *Clematis gouriana*, *Pongamia pinnata*, *Crinum* sp., *Psidium guajava*, *Bombax ceiba*, *Scirpus* sp., *Borassus flabellifer* and Kash (*Saccharum spontaneum*), although the main vegetation was formed by the populations of Kash (*Saccharum spontaneum*), Shon (*Imperata cylindrica*), Jhonjoni (*Crotalaria juncea*) and Horma Ghash (*Hemarthria* sp.). The undergrowths usually found in other open areas dominated by these grasses, included Kalia Lata (*Derris trifoliata*), *Vitis* sp. and Shingra (*Cynometra ramiflora*). At this area, some scattered seedlings of Gewa (*Excoecaria agallocha*) and Goran (*Ceriops decandra*) were also observed to grow in fewer numbers. Inside the forest of Keora (*Sonneratia apetala*), the undergrowths were dominated by Hargoza (*Acanthus ilicifolius*), that was followed by Kalia Lata (*Derris trifoliata*), Angoor Lata (*Vitis* sp.) and Shingra (*Cynometra ramiflora*). The dense population of Kash (*Saccharum spontaneum*) and Shon (*Imperata cylindrica*) / Jhonjoni (*Crotalaria juncea*) usually growing on elevated, dry, sandy to sandy-loam soil might be indicative of the habitat consisted of such soil.

At the northern edge of Keora (*Sonneratia apetala*) forest, the dense populations of Kalia Lata (*Derris trifoliata*) was found to form a cover over the seedlings of Sundri (*Heritiera fomes*), Gewa (*Excoecaria agallocha*), Keora (*Sonneratia apetala*) and individuals of few other undergrowth species, due to which the normal growth of these plants was observed to be inhibited. Inside the Keora (*Sonneratia apetala*) forest, the undergrowths were found to be dominated by the frequently distributed or densely grown Hargoza (*Acanthus ilicifolius*), which was followed by Kalia Lata (*Derris trifoliata*) and Angoor Lata (*Vitis* sp.), Tambul Kanta (*Dalbergia spinosa*), Golpata (*Nypa fruticans*) and Chhitki Lata (*Flueggia virosa*).

Among the visited sites of the mangrove forests, comparatively larger number of Keora (*Sonneratia apetala*) seedlings along with few species of undergrowths were observed at the middle areas of Deemyer Char forest, where the undergrowth species were Kalia Lata (*Derris trifoliata*), Hargoza (*Acanthus ilicifolius*), Angoor Lata (*Vitis* sp.) and Chhitki Lata (*Flueggia virosa*). Few spots at the edge of Keora (*Sonneratia apetala*) forest were found to be dominated by Kalia Lata (*Derris trifoliata*). But inside the forest, the undergrowths were found to be dominated by Hargoza (*Acanthus ilicifolius*).

The overall biodiversity health status as well as the ecosystem of this very low saline site of Sunderbans, appeared to be very good at the northern tip both in terms of species richness as well as health of the individuals, but weak in rest of the site, although the frequency of healthy individuals belonging to few species was noticeable. A distinct successional trend for large-scale replacement of Dhanshi (*Porteresia coarctata*), *Saccharum spontaneum*, *Imperata cylindrica*, and *Crotalaria juncea*, mostly by Keora (*Sonneratia apetala*) and occasionally by the undergrowths such as Hargoza (*Acanthus ilicifolius*) and Kalia Lata (*Derris trifoliata*) was noticed. Introduction of a good number of plain land species was also noticeable. Although the natural destruction of biomass was not remarkable, but the instances of anthropogenic activities were apparent.

4.11. Site: KOTKA

At the sampling areas of this site, the common undergrowth species included Shingra (*Cynometra ramiflora*), Kalia Lata (*Derris trifoliata*), Angoor Lata (*Vitis* sp.), Tambul Kanta (*Delbergia spinosa*), Golpata (*Nypa fruticans*), Hental (*Phoenix paludosa*) and Hargoza (*Acanthus ilicifolius*) and the occasional ones included Gila Lata (*Entada pursaetha*), Assam Lata (*Mikania cordata*), Kash (*Saccharum spontaneum*), Shon (*Imperata cylindrica*), Jhanjhoni (*Crotalaria juncea*) and Bholā (*Hibiscus tiliaceus*).

At the sampling area near the north bank of Jamtala Khal, visited in both rainy and winter seasons, the dominating undergrowth species were Gila Lata (*Entada pursaetha*) and Shingra (*Cynometra ramiflora*). At this area, the mature individuals of Gila Lata (*Entada pursaetha*) were observed to grow aggressively and thereby inhibiting the normal growth of many trees of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*). The individuals of Shingra (*Cynometra ramiflora*) were found to be small to medium-sized trees and largest among the visited sites. Beside the individuals of this species, sometime the individuals of Kalia Lata (*Derris trifoliata*), Angoor Lata (*Vitis* sp.), Hental (*Phoenix paludosa*) and Sundri Lata were occasionally noticed here and there. Assam Lata (*Mikania cordata*) and Tambul Kanta (*Delbergia spinosa*) were noticed to grow aggressively at a small place, partially covering the canopies of Gewa and Sundri. The individuals of Hental (*Phoenix paludosa*) were mostly of similar nature to that found inside the forest of the visited sites of fresh water zone. At open, dry and less clayey soil, species like *Cyperus* sp. was found to form dense populations.

At the sampling area near the Jamtala Watch Tower beside the south bank of Jamtala Khal, the dense populations of Kash (*Saccharum spontaneum*), Shon (*Imperata cylindrica*), Jhonjhoni (*Crotalaria juncea*) with scattered clumps of other few sedges were found to be mixed with some scattered individuals of Gewa (*Excoecaria agallocha*) in both seasons. But the individuals of these grasses and sedges were not found to grow within the populations of Gewa (*Excoecaria agallocha*) or of Sundri (*Heritiera fomes*). Therefore, Gewa (*Excoecaria agallocha*) might have a tendency to migrate to the different habitats (habitat of the above-mentioned grasses or sedges) at which normally they don't grow. Further observation is needed to ensure this fact. Inside this forest area, the seedlings of stunted and slender individuals of Hental (*Phoenix paludosa*) were found to grow more dominantly than that of other undergrowth species like Hargoza (*Acanthus ilicifolius*) and Gila Lata (*Entada pussaetha*). Individuals of Bhola (*Hibiscus tiliaceus*) were very restricted in distribution. The individuals of undergrowth species were rare inside the deep forest area where mostly the healthy seedlings and some

saplings of Sundri (*Heritiera fomes*) were found to grow frequently. Some seedlings and some saplings of Gewa (*Excoecaria agallocha*) were also found to grow at this sampling area. The healthy mature individuals of these species were not found to be affected by the undergrowth species. The medium to large-sized healthy individuals of Golpata (*Nypa fruticans*) were observed in restricted distribution mostly at and beside the canal and occasionally inside the forest near the bank of the canal at both sampling areas. At both the sampling areas, the plant diversity was visualised to be healthy, but older near the north bank and poorer near the south bank of Jamtala Khal.

At sampling area around and near the Kotka Forest Office, visited only during rainy season, the undergrowths were mostly represented by Nayantara (*Catharanthus roseus*), Akonda (*Calotropis procera*), Jhonjhoni (*Crotalaria juncea*), Thankuni (*Centella asiatica*), Durba grass (*Cynodon dactylon*), *Axonopus compressus*, Kochu (*Colocassia esculanta*), *Urena* sp., *Sida* sp. and *Cyperus* sp. etc. At this part of sampling area, the only undergrowth species, which usually grows in the mangrove forest, was Hargoza (*Acanthus ilicifolius*). At the sampling area in a mixed forest mainly of Sundri (*Heritiera fomes*), Gewa (*Excoecaria agallocha*) and Goran (*Ceriops decandra*) situated at about 1.5 km north from the Kotka Forest Office and visited only during rainy season, the undergrowths were found to be dominated by Kalia Lata (*Derris trifoliata*), which was followed by Hargoza (*Acanthus ilicifolius*), Hental (*Phoenix paludosa*) and Chhitki Lata (*Flueggia virosa*). At the edge of this forest area, the soil was comparatively more sedimented and the dominating species of undergrowth were Golpata (*Nypa fruticans*) and Hargoza (*Acanthus ilicifolius*). The diversity of undergrowth species was found to decrease gradually towards the deep forest, where mainly the seedlings of Sundri (*Heritiera fomes*), Gewa (*Excoecaria agallocha*) and Goran (*Ceriops decandra*) along with the individuals of Kalia Lata (*Derris trifoliata*) were found to grow.

At this moderately high saline site of Sundarbans, the overall biodiversity health status as well as the ecosystem appeared to be good in terms of species richness,

frequency, health status and their regeneration except at the sampling areas beside the north bank of Jamtala Khal, although apparently poor diversity was observed in most of the parts inside the forests. A pronounced successional trend for the replacement of Keora (*Sonneratia apetala*) mostly by Sundri (*Heritiera fomes*) and occasionally by Gewa (*Excoecaria agallocha*) was observed. Introduction of a few plain land species was also recorded at two sampling areas. At one sampling area (north of Jamtala Khal), remarkable disturbance to the plant diversity through encroachment and destruction by visiting poor people was noticed. Natural destruction of biomass by different causal agents, such as insects, birds, woodborers, wood-decaying microorganisms and other animals was also observed but was restricted to Keora (*Sonneratia apetala*) and Bain (*Avicennia officinalis*) forest.

4.12. Site: DHANSHIDDHER CHAR

At the visited sampling areas of Dhansidder Char, the undergrowth species *Kalia lata* (*Derris trifoliata*) was most commonly found, which was followed by Shingra (*Cynometra ramiflora*) and Hental (*Phoenix paludosa*). Individuals of Hargoza (*Acanthus ilicifolius*), Golpata (*Nypa fruticans*) and Chhitki Lata (*Flueggia virosa*) were very rare. In respect to undergrowths, the seedlings of Sundri (*Heritiera fomes*) were found in greater number in all sampling areas. The seedlings of Gewa (*Excoecaria agallocha*) were found occasionally. At this site, the frequent presence of *Kalia Lata* (*Derris trifoliata*) along with Shingra (*Cynometra ramiflora*), Hental (*Phoenix paludosa*) and Golpata (*Nypa fruticans*) and Hargoza (*Acanthus ilicifolius*) were observed to be correlated with the suitable habitat for the successful natural formation of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*).

The overall biodiversity health status, at this site of Sundarbans, appeared to be good at the margins in terms of species richness, frequency as well as health of the individuals, although apparently poor diversity was observed in most of the areas

inside the forests. A distinct successional trend for the replacement of Poshur (*Xylocarpus mekongensis*) by Sundri (*Heritiera fomes*) and initiation of Gewa (*Excoecaria agallocha*) was noticed. Remarkable disturbance to the plant diversity through encroachment and destruction by visiting poor people and natural destruction of biomass by different causal agents, such as insects, birds, woodborers, the wood-decaying microorganisms and other animals was not observed at this site.

4.13. Site: KNM COLLECTION CENTER

The undergrowth at the sampling area, adjacent to Khulna Newsprint Mill Collection Center, was found to be dominated by Tiger Fern/Hudo (*Achrosticum aureum*), which was followed by Amoor (*Amoora cucullata*). Distribution of other undergrowths like Hargoza (*Acanthus ilicifolius*), Baila Ghash (*Myriostachya wightiana*) and Kalia lata (*Derris trifoliata*) were found to be confined at the edges of the forest, the soil of which was sandy loam and slightly clayey, but not rich in humus. The surrounding areas of the clumps or clusters of Tiger Fern/Hudo (*Achrosticum aureum*) were comparatively more elevated (2-4 inch) than the adjacent clayey and slightly depressed areas accumulating tidal water. These more clayey areas with accumulated water were observed mostly without any undergrowth, although some seedlings of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) were occasionally found to occur. The reason for the absence of other undergrowth species, like Kalia Lata (*Derris trifoliata*), Shingra (*Cynometra mimosoides*), Hargoza (*Acanthus ilicifolius*), Chhitki Lata (*Flueggia virosa*) etc. that were found commonly in the similar type of forest in other sites was not revealed.

At this area, many mature trees of Sundri (*Heritiera fomes*) were observed to be severely affected by the top-dying. The number of large and healthy tree species was very few. Most of the trees of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) were small to medium-sized with slender trunk, although the seedlings of these species, especially of Sundri (*Heritiera fomes*) were frequently observed.

The overall biodiversity as well as the ecosystem of this site of Sundarbans appeared to be sick both at the margins and in the inside of the forests as well. Apparently poor diversity was observed in most of the areas inside the forests. A pronounced successional trend for the replacement Sundri (*Heritiera fomes*) by Gewa (*Excoecaria agallocha*) was observed. Although remarkable disturbance to the plant diversity through encroachment and destruction by visiting poor people was not observed, but natural destruction of biomass mainly of Sundri (*Heritiera fomes*) by different causal agents, such as insects, birds, woodborers, wood-decaying microorganisms and especially through top-dying was observed at this site.

4.14. Site: KEORABUNIA /VOJVOJAR CHAR

At this site the undergrowths were pioneered by Dhanshi (*Porteresia coarctata*) and Bailla Ghash (*Myriostachya wightiana*) jointly and followed by Golpata (*Nypa fruticans*), Hargoza (*Acanthus ilicifolius*), Hental (*Phoenix paludosa*), Amoor (*Amoora cucullata*), Kalia Lata (*Derris trifoliata*) and Gila Lata (*Entada parsaetha*) in Keora forest. Along with these undergrowths, the seedlings of Sundri (*Heritiera fomes*) and Keora (*Sonneratia apetala*) were also found. Dhanshi (*Porteresia coarctata*) and Bailla Ghash (*Myriostachya wightiana*) were observed to form mixed populations. Following these populations, the individuals of Hargoza (*Acanthus ilicifolius*) and Hental (*Phoenix paludosa*) were observed to form dense clusters.

The undergrowths of Sundri-Gewa forest were dominated by Amoor (*Amoora cucullata*) and Kalia Lata (*Derris trifoliata*) that were followed by Golpata (*Nypa fruticans*), Hental (*Phoenix paludosa*) and Bawali Lata (*Sarcolobus globosus*). Under the canopy of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*), dense growth of Sundri seedlings followed by occasional presence of Gewa and or Goran (*Ceriops decandra*), were found. In comparatively depressed deep clayey areas holding shallow layer of tidal water, the undergrowths were either absent or rare and few scattered seedlings of Sundri (*Heritiera fomes*) were observed

occasionally. The healthy clusters of Golpata (*Nypa fruticans*), Hental (*Phoenix paludosa*) and Hargoza (*Acanthus ilicifolius*) were found to be scattered on few slightly elevated less clayey spots, especially besides the more clayey depressed areas holding tidal water.

The overall status of biodiversity at this site of Sundarbans appeared to be unhealthy, in terms of richness and frequency of species, especially inside the forests. But the overall ecosystem was assumed to be promising. A distinct successional trend for the replacement of Keora (*Sonneratia apetala*) by Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) was observed. Remarkable disturbance to the plant diversity through encroachment and destruction by visiting poor people and the natural destruction of biomass by different causal agents, such as insects, birds, woodborers, wood-decaying microorganisms or other animals were not observed at this site.

4.15. Site: DOBEKI-DANOKHALI

The sampling areas of this site were mostly occupied by the scattered bushes of Goran (*Ceriops decandra*) and sometimes by the small to medium-sized individuals of Gewa (*Excoecaria agallocha*). Inside the forest, undergrowths were totally absent especially under and between the bushes of Goran (*Ceriops decandra*) on the elevated places of dry sandy-loam soil. Distribution of undergrowths was mainly restricted to some places covered with mixed vegetation of Gewa (*Excoecaria agallocha*), Keora (*Sonneratia apetala*), Kakra (*Bruguiera gymnorhiza*) and Goran (*Ceriops decandra*). These undergrowths were dominated by Tiger Fern/Hudo (*Achrosticum aureum*), that were irregularly followed by Hental (*Phoenix paludosa*), Kalia Lata (*Derris trifoliata*) and Hargoza (*Acanthus ilicifolius*).

The clumps of Tiger Fern/Hudo (*Achrosticum aureum*) and Hental (*Phoenix paludosa*) were observed to grow on slightly raised places, whereas, the individuals of Kalia Lata (*Derris trifoliata*) and Hargoza (*Acanthus ilicifolius*) were

found mostly on the plain lands beside the trees of Gewa (*Excoecaria agallocha*) and Goran (*Ceriops decandra*), but occasionally. Small populations of Dhanshi (*Porteresia coarctata*), inhabiting scattered seedlings of Keora (*Sonneratia apetala*) and a few seedlings of Goran (*Ceriops decandra*), were observed on sloppy and clayey surfaces near slightly depressed small canal and at the slopes of Kolagachhia Khal. Seedlings of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) were rarely found on the slope of Kolagachhia Khal dominated by Dhanshi (*Porteresia coarctata*), although they were more or less common within the populations of the same grass (Dhanshi) near the very small canal flowing towards the deep forest. The seedlings of Gewa (*Excoecaria agallocha*), Sundri (*Heritiera fomes*) and Goran (*Ceriops decandra*) were more frequent, sometimes in dense growth, within the mixed forest of Goran (*Ceriops decandra*) and Gewa (*Excoecaria agallocha*) at which definite canopy could not be distinguished. But these seedlings were rare at the places dominated only by Goran (*Ceriops decandra*). None of the individuals of Gewa (*Excoecaria agallocha*) and Sundri (*Heritiera fomes*) appeared to be quite healthy and tall.

The overall biodiversity at this site of Sundarbans did not appear to be good in terms of richness, frequency and biomass of different species both at the margins and inside the forests, although the growth and frequency of Goran (*Ceriops decandra*) was noticeable. Some places of the sampling area were quite inundated. The plant diversity in most of the parts inside the forests was assumed to be poor. A pronounced successional trend for the replacement of Bain (*Avicennia officinale*) by Goran (*Ceriops decandra*) and Gewa (*Excoecaria agallocha*) was observed. Remarkable disturbance to the plant diversity through encroachment and destruction by visiting poor people and the natural destruction of biomass by different causal agents, such as insects, birds, woodborers, wood-decaying microorganisms and other animals were not observed at this site.

4.16. Site: DUBEKI

At this forest area the undergrowths were rare or absent inside the forest except only a few individuals of Kholshi (*Aegiceras corniculata*) and Kalia Lata (*Derris trifoliata*) but were poorly represented by Kalia Lata (*Derris trifoliata*), Hargoza (*Acanthus ilicifolius*), Tambul Kanta (*Dalbergia spinosa*) and Kholshi (*Aegiceras corniculata*) near the edges. Few individuals of Kalia Lata (*Derris trifoliata*) were found to form a cover over few young trees of Gewa (*Excoecaria agallocha*) and few mature shrubs of Goran (*Ceriops decandra*) but not so severely.

Some traces of certain undergrowth species were observed in the Goran (*Ceriops decandra*) dominated or its monotypic forests, such as of Hental (*Phoenix paludosa*), Tiger Fern; Hudo (*Achrosticum aureum*), Kalia Lata (*Derris trifoliata*), Hargoza (*Acanthus ilicifolius*), Kholshi (*Aegiceras corniculata*) and Tambul Kanta (*Dalbergia spinosa*). These species of undergrowth were not found to be detrimental for the healthy and profusely branched Goran (*Ceriops decandra*) as well as for Keora (*Sonneratia apetala*), Pashur (*Xylocarpus mekongensis*) and Kakra (*Bruguiera gymnorrhiza*).

At this site, the overall status of biodiversity appeared to be ill in terms of richness, frequency and biomass of different species both at the margins and inside the forests, although the growth and frequency of Goran (*Ceriops decandra*) was noticeable. Some places of the sampling area were quite inundated. The plant diversity in most of the places inside the forests was assumed to be poor. Most of the undergrowths were observed to be ill-developed. A pronounced successional trend for the replacement of Keora (*Sonneratia apetala*) and *Xylocarpus mekongensis* (Pashur) by Goran (*Ceriops decandra*) and Gewa (*Excoecaria agallocha*) in association with Bain (*Avicennia officinalis*), Sundri (*Heritiera fomes*) and Kakra (*Bruguiera gymnorrhiza*) was observed. Remarkable disturbance to the plant diversity through encroachment and destruction by visiting poor people and natural destruction of

biomass by different causal agents, such as insects, birds, woodborers, wood-decaying microorganisms and other animals were not observed at this site.

4.17. Site: HODDA

At the sampling site of this forest area, two types of undergrowths were found. Near the edges of the canal, the undergrowth was found to be dominated by Baila Ghash (*Myriostachya wightiana*), which was followed by Hargoza (*Acanthus ilicifolius*). Other associate species like Kalia Lata (*Derris trifoliata*), Hental (*Phoenix paludosa*) and Bawali Lata (*Sarcolobus globosus*) were seen occasionally. Along with these undergrowths, seedlings of Sundri (*Heritiera fomes*), Kakra (*Bruguiera gymnorhiza*) and Gewa (*Excoecaria agallocha*) were also observed.

The undergrowths inside the forest, both at the open places between the canopies and under the canopies of Kakra (*Bruguiera gymnorhiza*) and Sundri (*Heritiera fomes*), were basically represented by Lata Sundri (*Brownlowia lanceolata*). The individuals of Kalia Lata (*Derris trifoliata*) and Hental (*Phoenix paludosa*) were found occasionally in clusters. The individuals of Hargoza (*Acanthus ilicifolius*) were very rare. Although some individuals of Kalia Lata (*Derris trifoliata*) were observed to be healthy but almost all of the Hental (*Phoenix paludosa*) and Hargoza (*Acanthus ilicifolius*) were observed to be ill-developed or stunted. Both the seedlings and saplings were dominated by Sundri (*Heritiera fomes*). The seedlings of Sundri (*Heritiera fomes*) were followed by Kakra (*Bruguiera gymnorhiza*) and Gewa (*Excoecaria agallocha*). Saplings of Kakra (*Bruguiera gymnorhiza*) were very rare and that of Gewa (*Excoecaria agallocha*), Amoor (*Amoora cucullata*) and Dahur (*Cerbera manghus*) were occasional.

The overall status of biodiversity at this site appeared to be good both at the margins and inside the forest. Undergrowths were quite absent at some places under the canopies of Kakra (*Bruguiera gymnorhiza*) and Sundri (*Heritiera fomes*). The plant diversity in most of the places inside the forests was assumed to be rich.

Most of the undergrowths and trees except Goran (*Ceriops decandra*) were observed to be very healthy. The successional trends at this site were difficult to understand, but there might be the gradual and continuous replacement of *Sonneratia apetala* (Keora), *Xylocarpus mekongensis* (Pashur), and *Avicennia officinalis* (Bain) by Kakra (*Bruguiera gymnorhiza*) and Sundri (*Heritiera fomes*). Remarkable disturbance to the plant diversity through encroachment, destruction by visiting poor people and the natural destruction of its biomass by different causal agents, such as insects, birds, woodborers, wood-decaying microorganisms and other animals were not observed at this site.

4.18. Site: KALAGACHIA

Association of undergrowths was not good in this forest. The representative undergrowth species that were found to grow in this forest included Hargoza (*Acanthus ilicifolius*), Kholshi (*Aegiceras corniculata*), Kalia lata (*Derris trifoliata*) Golpata (*Nypa fruticans*) and Bawali lata (*Sarcolobus globosus*). Among all other visited sites, the growth performance and populations of Kholshi (*Aegiceras corniculata*) was observed to be better in this forest. Moreover, Hargoza (*Acanthus ilicifolius*) was dominating, followed by Hental (*Phoenix paludosa*) and Kalia lata (*Derris trifoliata*). The aggressiveness of Kalia lata was remarkable. Rate of seedling regeneration was fair. A good number of Sundri (*Heritiera fomes*) and Amoor (*Amoora cucullata*) saplings was found sprouting.

The overall status of biodiversity at this site did not appeared to be good in terms of richness, frequency and biomass of different species, except Goran (*Ceriops decandra*), both at the margins and inside the forests. But the overall ecosystem assumed to be promising. Some places of the sampling area were observed as inundated. A distinct successional trend for the replacement of Bain (*Avicennia officinalis*) and Pashur (*Xylocarpus mekongensis*) by Goran (*Ceriops decandra*) and Gewa (*Excoecaria agallocha*) was also observed. Remarkable disturbance to the

plant diversity through encroachment and destruction by visiting poor people and natural destruction of its biomass by different causal agents, such as insects, birds, woodborers, wood-decaying microorganisms and other animals were not observed at this site.

4.19. Site: PUSHPAKATHI

At this site, most of the undergrowth species were found to grow along the margins, some of which were distributed up to the first layer of the forest. A total of six undergrowth species were observed at the edges of the forest, viz. Hargoza (*Acanthus ilicifolius*), Hental (*Phoenix paludosa*), Kalia lata (*Derris trifoliata*), Tiger-fern (*Achrosticum aureum*), Golpata (*Nypa fruticans*) and Kholshi (*Aegiceras corniculata*) in both seasons. Among these, Hargoza (*Acanthus ilicifolius*) was the most dominant followed by Hental (*Phoenix paludosa*) and Kalia lata (*Derris trifoliata*). But no undergrowth species was observed inside the forest except some scattered individuals of Kalia lata (*Derris trifoliata*). Invasive effect of Kalia lata was prominent only at the margins of the visited area.

The biodiversity health at this site did not appear to be good in terms of frequency and biomass of different species, especially inside the forests, although the healthy individuals of Goran (*Ceriops decandra*) was observed to grow frequently and the regeneration of Gewa (*Excoecaria agallocha*) and Goran (*Ceriops decandra*) appeared to be fair. Some places of the sampling areas, especially between the canopies of Goran (*Ceriops decandra*) were observed to be inundated. The successional trends at this site was not understood clearly, but the population of Bain (*Avicennia officinalis*) and Poshur (*Xylocarpus mekongensis*) might have to be restricted or replaced by the initiation and frequent formation of Goran (*Ceriops decandra*) by Gewa (*Excoecaria agallocha*). Remarkable disturbance to plant diversity through encroachment and destruction by visiting poor people and natural destruction of its biomass by different causal agents, such as insects, birds,

woodborers, wood-decaying microorganisms and other animals were not observed at this site.

4.20. Site: NEAR KOIKHALI

The most commonly found undergrowth species of this sampling area was Kalia Lata (*Derris trifoliata*), the individuals of which were found to be mostly well-developed and affecting negatively the growth of Sundri (*Heritiera fomes*) and occasionally of Gewa (*Excoecaria agallocha*). Among the associate undergrowths, Hargoza (*Acanthus ilicifolius*) was comparatively common, but the individuals of which were not found to grow densely. Hargoza (*Acanthus ilicifolius*) was followed by Tiger Fern/Hudo (*Achrosticum aureum*), the small population of which was formed by the densely grown individuals were found occasionally. Few clusters of Hental (*Phoenix paludosa*) and Golpata (*Nypa fruticans*) individuals with inadequate growth were also observed. The individuals of Amoor (*Amoora cucullata*) and Noonia (*Aegialitis rotundifolia*) were rare, but healthy. Most of these undergrowths were observed in open places between the thin canopies of Gewa (*Excoecaria agallocha*) and Sundri (*Heritiera fomes*) and thick cover of Goran (*Ceriops decandra*). Although some undergrowth were found under the canopies of sparsely grown Gewa (*Excoecaria agallocha*) and Sundri (*Heritiera fomes*) trees with retarded growth but these were very rare under Goran (*Ceriops decandra*). In most cases, the mature individuals of Goran (*Ceriops decandra*) were found to be associated with their dense seedlings, although their seedlings were also observed in good number in open places. The seedlings of Goran (*Ceriops decandra*) were found to be followed by that of Sundri (*Heritiera fomes*). The seedlings of other tree species were very occasional.

At this sampling areas of this site, almost all the trees of Sundri (*Heritiera fomes*) were small, ill developed and growth of most of the individuals were found to be checked by the aggressively grown Kalia Lata (*Derris trifoliata*) over their stem and branches. The individuals of Pashur (*Xylocarpus mekongensis*) were mostly well-

developed, mature and with profuse branching and those of Bain (*Avicennia officinalis*) were mostly medium-sized and without profuse branching. The mature individuals of Goran (*Ceriops decandra*) were found to be mostly well-developed shrubs with profuse and very healthy branching.

Although the individuals of Sundri (*Heritiera fomes*) and sometimes of Goran (*Ceriops decandra*) were observed to be adversely affected by Kalia Lata (*Derris trifoliata*), but that of Goran (*Ceriops decandra*) were not observed to be affected by this climber. As in most other visited areas, the individuals of Golpata (*Nypa fruticans*) were also found to grow at heavily sedimented spots beside the canal and that of Hental (*Phoenix paludosa*) with stunted growth at raised and less sedimented spots inside the forest.

The overall biodiversity health status at this site was not observed to be good in terms of the species richness, frequency and biomass of different species both at the margins and inside the forests, although growth performances of Goran (*Ceriops decandra*), in association of Gewa (*Excoecaria agallocha*) was remarkable. Some places of the sampling areas, especially between the canopies of Goran (*Ceriops decandra*) were observed to be quite inundated. A successional trend for the replacement of *Xylocarpus mekongensis* (Pashur) and *Avicennia officinalis* (Bain) by Goran (*Ceriops decandra*) and Gewa (*Excoecaria agallocha*) was observed to be in progress. Remarkable disturbance to plant diversity through encroachment and destruction by visiting poor people the natural destruction of its biomass by different causal agents, such as insects, birds, woodborers, wood-decaying microorganisms and other animals were not observed at this site.

4.21. Site: EAST PART OF RAIMANGAL RIVER

In comparison with the other visited sites of west Sunderbans, the highest number of undergrowth species were found to occur at this site. Assemblage of maximum number of undergrowth species in this site might be due to low salinity and

sediment deposition through frequent inundations. These species were Hargoza (*Acanthus ilicifolius*), Hental (*Phoenix paludosa*), Kalia-lata (*Derris trifoliata*), Golpata (*Nypa fruticans*), Tiger fern (*Achrosticum aureum*), Nona-Jhau (*Tamarix indica*), Lata-Sundri (*Brownlowia lanceolata*) and Bawali lata (*Sarcolobus globosus*) and were mostly distributed at the edges of the forest. A remarkable number of undergrowth species were found to grow in some areas of this forest, which might be due to the presence of small canals or depressions over these areas. Among the undergrowths, Hargoza (*Acanthus ilicifolius*) was found to dominate, and followed by Kalia lata (*Derris trifoliata*). Populations of Hental (*Phoenix paludosa*) and Golpata (*Nypa fruticans*) were also noticeable.

At this site, although the overall ecosystem and growth performance of Goran (*Ceriops decandra*) and Gewa (*Excoecaria agallocha*) seemed to be good, but the biodiversity health status did not appear to be so good, especially in terms of species richness and frequency of healthy individuals. Regeneration of mangrove seedlings, viz. Gewa (*Excoecaria agallocha*), Sundri (*Heritiera fomes*) and Goran (*Ceriops decandra*) were very good especially inside the forest. Some places of the sampling areas, especially between the canopies of Goran (*Ceriops decandra*) were observed to be quite inundated. The successional trend at this site was confusing. But the replacement of Bain (*Avicennia officinalis*), Kakra (*Bruguiera gymnorhiza*) and Poshur (*Xylocarpus mekongensis*) by the frequent initiation of Goran (*Ceriops decandra*), Gewa (*Excoecaria agallocha*) and Sundri (*Heritiera fomes*) was also observed to be in progress. Instances of a small scale disturbance to plant diversity through encroachment and destruction by visiting poor people were observed, but natural destruction of biomass by different causal agents, such as insects, birds, woodborers, wood-decaying microorganisms and other animals were not remarkable at this site.

4.22. Site: DUBLARCHAR

In the visited areas of Dublarchar, a total of six undergrowth species was recorded in dry season, and these were Hental (*Phoenix paludosa*), Kalia lata (*Derris trifoliata*), Hargoza (*Acanthus ilicifolius*), Bhola (*Hibiscus tiliaceus*), Angoor lata (*Vitis sp.*) and Kholshi (*Aegiceras corniculata*). But among these undergrowth species Hargoza (*Acanthus ilicifolius*) and Hental (*Phoenix paludosa*) were frequently noticed. Presence of Kalia lata (*Derris trifoliata*) and their invasive effects were low. Bhola (*Hibiscus tiliaceus*) and Angoor lata (*Vitis sp.*) was found in the riverbank side. Only a few Kholshi (*Aegiceras corniculata*) was found to occur. Besides these species, some other undergrowths, mainly some grasses were found to grow in the inundated and sedimented forest areas. The main mangrove tree species of this forest site were mostly Gewa (*Excoecaria agallocha*) and Kakra (*Bruguiera gymnorrhiza*) with understorey of Goran (*Ceriops decandra*). A few Kirpa (*Corallia bracheata*), Poshur (*Xylocarpus mekongensis*) and Sundri (*Heritiera fomes*) were also noticeable. The growth of Sundri (*Heritiera fomes*) was not satisfactory.

Although the overall ecosystem of this site was observed to be promising and growth and development of Goran (*Ceriops decandra*) was good and the association of undergrowth species was fair, but the overall biodiversity health did not appear to be good. A succesional trend for the replacement of Keora (*Sonneratia apetala*) and Poshur (*Xylocarpus mekongensis*) by Goran (*Ceriops decandra*) and Gewa (*Excoecaria agallocha*) was observed to be in progress. It was also observed that the extension of mangrove forest was remarkably disturbed due to flood hit and sand deposition. Encroachment and destruction of forest by fishermen was high in this region. Forest destruction by natural causes, viz.: insects, birds, wood-borers, fungal organisms wood-decay and other animals was remarkable. Interferences and encroachment due to the presence of seasonal fishermen's settlement were notable in this site.

4.23. Site: MANDABARIA

In the visited sampling area of this site only four undergrowth species were recorded in dry season and these were Hargoza (*Acanthus ilicifolius*), Hental (*Phoenix paludosa*), Kalia lata (*Derris trifoliata*) and Tiger fern/Hudo (*Achrosticum aureum*). The populations and invasiveness of Kalia lata (*Derris trifoliata*) were prominent here. The presence of Tiger-fern (*Achrosticum aureum*) was centered at the peripheries of the forest mainly along with the canal sides. The populations and growth of Hental (*Phoenix paludosa*) were also good. But the presence of Hargoza (*Acanthus ilicifolius*) was scant in terms of total phytodiversity association. Some other species, viz. Kontikiani (*Solanum xanthocarpum*), Moina kanta (*Xeromphis spinosa*), Dhaki jam (*Syzigium fruticosum*), Dhundul (*Xylocarpus granatum*), some herbaceous legume (*Crotalaria saltiana*) and some grasses (Sun-grass) and sedges were found to grow.

The overall status of biodiversity health of this site did not appear to be good, although the frequency, growth and development of the individuals, especially of Goran (*Ceriops decandra*) were noticeable. The population of Kirpa (*Corallia bracheata*), Bain (*Avicennia officinalis*), Dhundul (*Xylocarpus granatum*) and Keora (*Sonneratia apetala*) were observed to be reduced or replaced by the newly initiated Goran (*Ceriops decandra*) and Gewa (*Excoecaria agallocha*). Many forest trees were seen to be destroyed along the sea-side due to high flood hit and natural catastrophe, reminiscent of which still existed. Inside the forest a good number of saplings of different mangrove species was observed and the rate of regeneration was noticeable. The extreme southern part of this forest has been regularly affected by natural calamities, specially wind and tidal hits. Forest floors in this part have been destroyed due to regular cyclone, the reminiscence of which could be seen by the existing dead trees. Due to severe natural catastrophe, forest areas have been reduced in different places and many small clear areas have developed.

4.24. Site: KALIRCHAR

It was exceptionally noticeable that no undergrowth species was found to grow in this site in winter season except some unhealthy Hargoza (*Acanthus ilicifolius*) in the first layer of the forest and some associated species like Nona-Jhau (*Tamarix indica*), Amoor (*Amoora cucullata*), Moina kanta (*Xeromphis spinosa*), Kutum-lata (*Delbergia spinosa*) and Dhanshi (*Porteresia coarctata*) of scattered occurrence (Plate-15) including some grasses and sedges.

This was an unusual habitat formation sometimes that might form especially in mangrove biodiversity. Though the mangrove association in southern part was thin, the vegetation association was denser in northern side; especially the growth

performance of Goran (*Ceriops decandra*) was satisfactory along with good Gewa (*Excoecaria agallocha*) populations. The rate of seedling regeneration in southern part was low, but it was moderate or in some places, was very good in northern part. Some Nona-Jhau (*Tamarix*



Plate-15. Undergrowth diversity at Kalir Char.

indica) and unhealthy Sundri (*Heritiera fomes*) were observed to be scatteredly grown. In Kalirchar-middle forest area, only three undergrowth species were found to grow, viz.: Hargoza (*Acanthus ilicifolius*), Kalia lata (*Derris trifoliata*) and Kholshi (*Aegiceras corniculata*), but their population were small. Hargoza (*Acanthus ilicifolius*) was observed to grow along the banks and in open or in thinly populated vegetation areas. The mode of Kalia lata (*Derris trifoliata*) was observed to be aggressive. At this site, most of the forest floors were observed as inundated

and formation of new forest areas was enhanced through huge and continuous sedimentation. Appearance of a good number of seedlings and saplings of different mangrove species in the deposited mud was also noticeable. Although the overall ecosystem was assumed to be promising, but its biodiversity was not observed to be healthy, especially in terms of species richness (Plate-15) and frequency of healthy individuals. A successional trend for the replacement of Keora (*Sonneratia apetala*) by Sundri (*Heritiera fomes*) was noticed. Encroachment and destruction of forest by anthropogenic activities and destruction of biomass by natural causes, viz.: insects, birds, woodborers, fungal organisms, wood-decay and other animals were not remarkable at this site.

CHAPTER-5**5. DISCUSSION**

In this investigation, all undergrowth species, including those that were designated as indicators in *Vide Inception Report* (p. 21-22) for Sundarbans mangrove ecosystem, were envisaged in order to justify their credibility and to select finally only those ones that can effectively be useful for the assessment of biodiversity health status in Sundarbans mangrove ecosystem. In order to test and validate their role, functions and correlation with the health status of biodiversity in field condition, two fifteen days field studies at 24 sites representing a wide cross-section of the entire Sundarbans mangrove ecosystem were accomplished in rainy and/or dry seasons. In the first visit, all undergrowths including the theoretically targeted ones growing commonly and occasionally in the selected sites of fresh and saline water zones (Table 5) were carefully observed and studied in terms of their qualitative features, distribution, diversity, association, ecological function and habitat features for the preliminary selection of indicator species. In the second visit, the short listed undergrowth species (Table 7 & Plate 23-29), tentatively selected after the first visit, were studied in detail with due attention especially in terms of their certain qualitative and quantitative features (Annexure 2.1-2.9) including their diversity status (Annexure 6a-28), ecological function, distribution, association and habitat features for the verification of their effectiveness for the assessment of biodiversity health status. The site-wise distribution, association and habitat features of the undergrowth species have been described in the observation and site description section. The status of species diversity, ecological function and indication, based especially on the

quantitative features, of undergrowths including the difficulties and confusions observed carefully during the field visits have been discussed below.

5.1. DIVERSITY STATUS

The status of species diversity of Sundarbans undergrowths has been assessed by the calculation of Shannon-Weiner diversity index ($H' = -\sum p_i \ln p_i$). Diversity indices for the undergrowth species (Annexure 6a-28) revealed that there is a positive correlation among higher diversity indices, spatial locations and existing environmental parameters, such as fresh water flow, salinity gradient and sedimentation load from east to west direction or vice versa. These general trends indicate that the Sundarbans biodiversity is much better in the nonhaline or oligohaline zones in comparison to that of the polyhaline zones i.e. biodiversity vary salinity gradient-wise (Table 2). In another sense, the plant diversity, especially the undergrowth diversity in term of species richness and the health status of ecosystem in most of the sites decreases strikingly, as one gradually moves from fresh water zones i.e. Eastern and North-Eastern (Plate 1-4, 9-12 & 16-17; Table 2-4) and South-Eastern Sundarbans to more saline zones i.e. Western



Plate-16. Plant diversity in Sundri-Gewa dominated forest of Sundarbans (South Dhabrivarani).

and South-Western Sundarbans (Plate 5-8, 13-15 & 18-20; Table 2-4). This is explicit in the values of diversity indices of the visited sites (Annexure 6a-28). This trend also exists in the forest types, i.e. from the Sundri-Poshur dominated forest towards the Sundri-Gewa, Sundri, Keora-Gewa, Gewa-Keora, Goran-Gewa, Goran-

Sundri and Goran-Keora dominated forests (Plate 11, 12, 16 & 18; Table 3). In almost all forest types, except Keora dominated forests and that in Char lands, the

plant diversity is comparatively poor in inside or deep (Plate 2 & 11) and rich at the margins or edges (Plate 1, 4, 9-10 & 12). The diversity values of few forest types, e.g. Sundri-Gewa, Keora-Sundri, Gewa-Sundri and Goran-Gewa dominated forests, not matching this trend might be due to the collection of data from the misrepresentative micro-habitats. Mixed forest of Sundri-Gewa-Goran-Keora or Sundri-Gewa-Keora in the



Plate-17. Indicativensess of Keya (*Pandanus foetidus*) to the healthy diversity of fresh water mangrove forest

moderately fresh water or mesohaline zones supported a number of undergrowth species, but Bhola, Keya and Shingra are unique to mostly Sundri and occasionally Sundri-Gewa dominated forests (Plate 17). Noticeably very poor diversity of undergrowths in western saline zones might be due to high salinity, adverse nature of habitat composed of compact sandy loam and wet soil not accumulating the tidal or rainwater and canopy shade formed by the bushes of densely grown Goran (*Ceriops decandra*) occupying most of the areas, in association with *Poshur* (*Xylocarpus mekongensis*) and Bain (*Avicennia officinalis*) and sometimes by Gewa (*Excoecaria agallocha*). The absence of undergrowths at slightly depressed and clayey areas between the canopies of few mangrove trees species, such as Sundri (*Heritiera fomes*) or Gewa (*Excoecaria agallocha*), as observed in few sites of fresh water or less saline water zones (eg. Jongra Beel, Mirgamari and Bojbhojar Char), might also be due to the repeated and stronger flow of tidal water, not allowing the settling and germination of seeds or propagules of undergrowth species over these areas. Further studies are needed to find out the actual reasons behind this phenomenon. The reason/s for low or high value of diversity indices of different sites may be further investigated. Forests and the associated undergrowths of higher saline sites are much more depauperated or

degraded than lower saline sites. The diversity of undergrowth species may be richer in relatively younger mangrove forest, as at Deemyer Char, than in older ones. The important question is that whether the health status of mangrove forest ecosystem should be envisaged in terms of i) diversity status, growth performances and biomass of all common plant species, ii) diversity status, growth performances and biomass of a single or few certain plant species, iii) growth performances and biomass formation by a single/few certain or iv) growth performances and biomass formation by all common plant species. If we consider the first set of terms for characterizing the health status of mangrove forest ecosystem, then it can be concluded that the higher values of Shannon Diversity Index and better growth performances including biomass formation by the undergrowths, like Hental (*Phoenix palludosa*), Golpata (*Nypa fruticans*), Bholā (*Hibiscus tiliaceus*), Keya (*Pandanus foetidus*) and Hargoza (*Acanthus ilicifolius*) etc. in nonhaline or oligohaline zones, might be correlated with better health status of mangrove forests (Plate 1, 4., 16 & 17).



Plate-18. Plant diversity in the monotypic Keora (*Sonneratia apetala*) forest of Sundarbans.

On the otherhand, the lower values of Shannon Diversity Index and poor growth performances and biomass formation by the undergrowths, like Hental (*Phoenix paludosa*) and Golpata (*Nypa fruticans*) in mesohaline or polyhaline zones, might be correlated with ill health status of the mangrove ecosystem. The diversity value of Shannon Diversity Indices for the undergrowths occurring throughout higher saline zones of Sundarbans forest ecosystem indicated that its health status is not better or rather sick in these areas. Field surveys and the available ecological data revealed that there are distinct forest associations and these can be visually

Table 2. Diversity status at the visited sites of the Sundarbans mangrove forest.

Sites	Shannon Diversity Index								AVE.
	Nonhaline zones		Oligohaline zones		Mesohaline zones		Polyhaline zones		
	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	
Jongra beel	2.0846	2.038							2.062
Mirgamari	1.5949	1.979							1.787
Panirghat	1.7132	1.797							1.755
Dhabrivarani			1.5321	1.880					1.706
Terabeka			1.6953	1.951					1.823
Patakata				1.875					1.875
Tiar Char				1.123					1.123
Pakhhir Char				1.538					1.538
Deemver Char			1.728	1.820					1.774
Kotka			1.677	1.5679					1.622
Dhanshid.Char			0.8734						0.873
KNM Office					0.4961				0.496
Keorabunia					1.5634				1.563
Dob.Danokhali							1.5634		1.563
Dobeki							0.8828		0.883
Hodda					1.3100				1.310
Koikhali							1.0326	1.559	1.296
Pushpa Kathi							1.280	1.288	1.284
Kalagachia							1.190	1.464	1.327
Dublar Char				1.820					1.820
Mandarbaria				1.609					1.609
Kalir Char						0.148			0.148

identified in the field, mainly by their dominance as determined by species abundance or presence/absence criteria. Further, these associations are predominately influenced or controlled by the existing geomorphological and hydrological characteristics. Because, in the Sundri-Gewa dominated forests recognized in the nonhaline and oligohaline zones, Hental (*Phoenix paludosa*) formed scattered small clumps both at the margins and inside the forests. Golpata (*Nypa fruticans*) formed both scattered small clumps and long strips of healthy individuals mostly at the edges of forests. These were followed by small to medium-sized populations of healthy individuals of Bholia (*Hibiscus tiliaceus*) growing in scattered fashion. The most abundant and densely populated communities of healthy individuals growing throughout most of the forest areas were found belonging to Keya (*Pandanus foetidus*) and Hargoza (*Acanthus*

Table 3. Diversity status at different forest types of Sundarbans mangrove ecosystem.

Forest types/association	Shannon Diversity Index			
	Nonhaline zones	Oligohaline zones	Mesohaline zones	Polyhaline zones
Sundri-Poshur-Kankra	2.062	0.873		
Sundri-Poshur-Bain	1.787			
Sundri-Poshur-Kankra-Bain	1.787			
Sundri-Gewa	1.755	1.706	0.496	
Sundri-Gewa-Goran		1.875		
Sundri		1.823		
Sundri-Gewa-Goran-Keora		1.622		
Sundri-Gewa-Keora		1.622		
Keora-Gewa-Sundri		1.774		
Keora-Gewa-Goran		1.123		
Keora-Sundri-Gewa			1.563	
Keora		1.538		
Gewa-Sundri	1.755	1.706		
Gewa-Sundri-Goran-Poshur				1.327
Gewa-Goran-Sundri-Keora				1.327
Gewa-Keora		1.820		
Gewa-Goran		1.609		
Goran-Gewa-Sundri				1.284
Goran-Gewa-Poshur				0.819
Goran-Sundri				1.033
Goran-Gewa			0.148	1.284
Goran-Gewa-Sundri				1.559
Goran-Gewa-Keora			0.148	
Goran-Keora-Poshur				0.883
Kankra-Gewa-Sundri-Poshur			1.310	
Average	1.829	1.591	0.733	1.189

ilicifolius). Two other species, e.g. Abetea (*Flagellaria indica*) and Shingra (*Cynometra ramiflora*) were found to grow as scattered individuals. Similarly, in the Sundri-Poshur-Kankra or Sundri-Kankra-Bain dominated forests of nonhaline and oligohaline zones, the undergrowths were represented by the same above-

Table 4. Diversity status and Hot Spot/s of the major zones Sundarbans mangrove forest ecosystem based on undergrowths.

Zones of the Mangrove Forests	Name of the visited sites	Average Diversity Status	Diversity Hot spot/s
WEST ZONE -between 'Raimangal River' and 'Arpangashia-Barapanga River-Betmargang'	Kalagachia, Koikhali, Eastern side of Rimangal River, Dobeki-Danokhali, Puspakathi, Mandarbari & Kalir Char.	1.111	Mandarbari
MIDDLE ZONE - between 'Arpangashia-Barapanga River-Betmargang' and 'Passur River'	Hodda, Jongra Beel, Keorabunia, KNM coll. cent., Patakata, Dubeki & Dhanshidder Char.	1.295	Jongra Beel & Patakata
EAST ZONE - between 'Passur River' and 'Baleswar River'	Mirgamari, Panirghat, Terabecka, Dhabribharani, Tear Char, Pakhir Char, Deemyer Char, Katka & Dublar Char.	1.661	Mirgamari, Panirghat, Terabecka, Dhabrivarani, Deemyer Char & Katka.

mentioned species, but uniquely characterized by having a pteridophytic climber, *Dhekia Lata* (*Stenochlaenapalustris*) with its profuse growth and abundant individuals. On the contrary to the nonhaline and oligohaline zones, Sundri-Gewa dominated forests of mesohaline zones were represented by small or large population of Hental, small-scattered clumps or isolated individuals of Golapata, Hargoza and Shingra of comparatively less healthy, ill-developed and dwarf individuals. Striking fact is the absence of Bhola and Keya, the keystone mangroves of nonhaline and oligohaline zones, in the Goran-Gewa or rarely Sundri-Gewa dominated forests of mesohaline and polyhaline zones (Table 3). Shingra was also absent in the mesohaline zones except in Hodda and in polyhaline zones of Sundarbans. The phenomenon of increase in the 'Diversity

Status' as well as number of 'Diversity Hot Spots' from the West Zone of Sundarbans towards the East Zone (Table 4) is also remarkable.

5.2. FUNCTIONS OF UNDERGROWTHS

The belt formed by the dense populations of Dhanshi (*Porteresia coarctata*), as observed in Sharonkhola, Tear Char, Pakhir Char (Plate 6, 14 & 19) and Deemyer Char and that of Malia Ghash (*Cyperus* spp.), as observed in Jongra beel and Mirgamari (Table 10) or their mixed populations with *Pseudoraphis* sp., Hogla (*Typha aungustata*), Shola (*Aeschynomene* sp.) and Bhat Kathi (*Bruguiera parviflora*) as observed in Sharonkhola may serve as pioneers of ecological succession in



Plate-19. Population of Dhanshi (*Porteresia coarctata*), the first pioneer of mangrove forest ecosystem.

mangrove ecosystem and facilitate the formation of new mangrove vegetation through accelerating the soil formation as well as binding and accumulating a good number of seeds of certain mangrove species that are floated and dispersed by water. The dense

homogenous or mixed populations of Nal Khagra (*Phragmites karka*), as observed in Mirgamari and Panirghat and South Dhabrivarani (Sharonkhola) (Plate 2 & 16), that of Kash (*Saccharum spontaneum*) and Shon (*Imperata cylindrica*) observed in Deemyer Char and Kotka and of Horma Ghash (*Hemarthrea* sp.), *Echinochloa crusgalli*, *Scirpus* sp., *Eriocaulon* sp., observed in Panirghat (Sharonkhola) near and or besides the canals and rivers may play an important role as second pioneers in ecological succession, particularly as soil binder as well as for binding and protecting some seeds of different mangrove species and thereby favoring the dispersal of these species indirectly.

The thin or moderately dense populations of the spiny-foliaged species with extensive root system like Keya (*Pandanus foetidus*), as observed in all nonhaline and oligohaline zones and Hargoza (*Acanthus ilicifolius*) observed in almost all visited sites, can also serve as soil binders as well as the accumulators of seeds, fruits or other propagules of different mangrove species especially near and at the banks of the canals, thereby favoring the distribution and formation of their new populations.

Under the large, vigorously curved and broad-leaved individuals of Bhola (*Hibiscus tiliaceus*) only few individuals of Keya (*Pandanus foetidus*) was observed or undergrowths were totally absent. This indicate that the mature individuals of Bhola (*Hibiscus tiliaceus*) might be inhibitor or detrimental to the formation of other undergrowth species excepting the few individuals of Keya (*Pandanus foetidus*). Although the dense populations of Bhola (*Hibiscus tiliaceus*) was observed to be detrimental to the undergrowth, but they might have an important role in ecological succession on the elevated sites. For example, the marginal populations of Nal Khagra (*Phragmites karka*) in Panirghat (Sharonkhola), following the dense populations of Dhanshi (*Porteresia coarctata*) and Malia Ghash (*Cyperus* spp.), was noticed to be suppressed and gradually blocked by the dense populations of mature and healthy individuals of Bhola (*Hibiscus tiliaceus*), which were noted to be followed gradually by that of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*).

The less frequent distribution of fewer number of undergrowth species inside the forests might not be detrimental to the normal growth of tree species. Instead, the dense growth of seedlings and saplings under and between the canopies of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) might have somewhat negative effect on the profuse growth of these trees, as observed in Panirghat, near Sharonkhola Range Office and South Dhabrivarani. The frequent presence of weak and slender saplings in the surrounding areas of mature trees with slender

and tall stems, less branching and rare presence of healthy and large trees might be corroborative for this assumption.

The observation inside the forests of Panirghat, South Dhabrivarani and near Terabeka Khal of Sharonkhola and of Kotka indicated that, although the aggressive growths of undergrowth species may retard the growth of tree seedlings or saplings, but their diversity become poorer and their growth become



Plate-20. Invasiveness of Kalia Lata (*Derris trifoliata*) at Pakhhir Char

retarded if some of the tree individuals become able to grow profusely with extensive branching, forming a dense canopy over the undergrowth. Under such canopy of trees, the undergrowths become non harmful for the growth of trees, they become replaced by the tree seedlings or saplings or even they become unable to grow, as observed under the canopy of some Poshur (*Xylocarpus mekongensis*) and Sundri (*Heritiera fomes*).

Kalia Lata (*Derris trifoliata*), an endemic indigenous climber poses to be a threat to many regenerating tree species seedlings owing to its aggressive twining and strangulating habit. This is widely distributed throughout the mangrove forests, irrespective of local ecological and environmental conditions. The dense populations of Kalia Lata (*Derris trifoliata*) forming a cover (Plate-20) over the seedlings and saplings of Sundri (*Heritiera fomes*), Gewa (*Excoecaria agallocha*), Keora (*Sonneratia apetala*) and over the individuals of few other undergrowth

species were observed to inhibit the normal growth of these plants, especially by checking the normal increase of stems both in diameter and length through binding them very tightly. Under the mature forest of Keora (*Sonneratia apetala*) no undergrowth was found. The reason behind this phenomenon might be the uninterrupted shade by the compact canopy of Keora (*Sonneratia apetala*) and the black layer of old humus which might not be favourable for the growth of other plants. Sometimes beside the absence of undergrowth in the old and mature forests of Keora (*Sonneratia apetala*), no seedlings nor saplings, especially of this tree species were observed that might be due to their excessive uprooting by the frequently visiting herds of deer and the existence of preparatory condition for the succession by next group of mangrove species. Assam Lata (*Mikania cordata*) is an alien weed species, restricted only in few sites of the nonhaline or oligohaline zones signaling its invasiveness in future.

At the visited forest areas of west Sunderbans, the normal growth of Gewa (*Excoecaria agallocha*) and Sundri (*Heritiera fomes*) with adequate branching, as observed in the visited site of fresh water zone, was found to be severely retarded that might be due to the vigorous growth of Goran (*Ceriops decandra*) and the high salinity and compactness of loamy to sandy loam soil. On the otherhand, in some sites of east Sunderbans (eg. Panirghat, South Dhabrivarani), the poor growth of most of the trees especially belonging to Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) might be due to the formation of huge number of seedlings and saplings under the sparse canopies and hard, dry, sandy-loam soil of the habitat. The less frequent distribution of fewer number of undergrowth species inside the forest might not be detrimental to the normal growth of tree species. Instead, the dense growth of seedlings and saplings under and between the canopies of Sundri (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*) might have somewhat negative effect on the profuse growth of these trees (eg. Panirghat, near Sharonkhola range office and South Dhabrivarani). The frequent presence of weak and slender saplings in surrounding areas of mature trees with slender and tall

Table-5. Phenological status of the investigated undergrowth species of Sundarbans during rainy and winter seasons.

Name of undergrowth species	Rainy Season			Winter Season		
	Flowering time	Fruiting time	Vegetative phase	Flowering time	Fruiting time	Vegetative phase
Bhola						██████████
Angoor lata	██████████					██████████
Kalia lata	██████████					██████████
Hargoza	██████████			██████████		██████████
Keya						██████████
Dhekia lata			██████████			██████████
Shingra						██████████
Gilalata			██████████			
Abatee	██████████					██████████
Choita boroi						██████████
Chitka lata	██████████					██████████
Hental						██████████
Assam lata			██████████	██████████		
Stephania			██████████			
Tiger fern			██████████			██████████
Bawali lata	██████████					██████████
Mamakala						
Golpatta	██████████					██████████
Dumur	██████████					
Lata Sundri	██████████					██████████
Tambul kanta			██████████			██████████
Nona jhau			██████████			██████████
Kutum lata	██████████					██████████

stems, less branching and rare presence of healthy and large trees might be corroborative for this assumption.

A good number of undergrowth species may be pinpointed to serve as indicator species for assessing health status as well as characterizing different habitat types

of Sundarbans mangrove ecosystem (Table 6-8). A good floral calendar might be formed on the basis of characteristic growth features and behavior of undergrowths. But preliminary observations on the basis of two 15 days field visits to the undergrowth species of the Sundarbans mangrove ecosystem in two seasons only can not give conclusive data evidence on the floral calendar of the concerned taxa. However, based on the limited information gathered during the two field visits a tentative floral calendar is prepared (Table 6).

5.3. INDICATIONS BY UNDERGROWTHS

The clumps and populations of Malia Ghash (*Cyperus* spp.) were found to be restricted to the newly formed open and depressed areas with deeply clayey soil, as observed in Jongra beel, Mirgamari and Sharon Khola. This indicates that, Malia Ghash (*Cyperus* spp.) might be an indicator to the fresh formation on the newly formed clayey soil of depressed areas. Sometimes the population of this species was found to be mixed with that of *Pseudoraphis* sp. This means that the mixed populations of Malia Ghash (*Cyperus* spp.) and *Pseudoraphis* sp. might also be indicative of the fresh formation on open depressed clayey areas.

The monotypic homogeneous or mixed populations of Dhanshi (*Porteresia coarctata*), was observed to be restricted as the first pioneer to the open, freshly sedimented and sandy habitat at the bank of canals and rivers, frequently washed out by the tidal waves, as observed in Panirghat (Sharon Khola), Tear Char, Pakhir Char and Deemyer Char. This fact indicates that the populations of Dhanshi (*Porteresia coarctata*) might be indicative for the new or fresh formation of soil,



Plate-21. Indication of Hargoza (*Acanthus ilicifolius*) to depressed clayey habitat.

necessary for the formation of new mangrove vegetation. The dense cover of Dhanshi (*Porteresia coarctata*) observed occasionally in the open areas within the monotypic forest of Keora (*Sonneratia apetala*), was associated with the scattered individuals of Hargoza (*Acanthus ilicifolius*), Bhat Kathi (*Bruguiera parviflora*) and Kholshi (*Aegiceras corniculata*) as observed in Pakhir Char, might be indicative to the maturing aspect of Keora dominated new mangrove forest.

The dense mixed populations of Horma Ghash (*Hemarthrea* sp.), *Echinochloa crusgalli*, *Scirpus* sp., Malia Ghash (*Cyperus* spp.), Kash (*Saccharum spontaneum*), *Eriocaulon* sp., Hogla (*Typha aungustata*) and Shola (*Aeschynomene* sp.) following the pioneer homogeneous one of Dhanshi (*Porteresia coarctata*), as observed in Panirghat (Sharonkhola) and Deemyer Char, might be indicative of the fresh formation on less clayey, sandy, open and shallowly raised habitats beside or adjacent to the bank of the canals and rivers of fresh or less saline water zone. The homogenous dense populations of Nal Khagra (*Phragmites karka*) may indicate the open, raised and less clayey habitats, as observed in Mirgamari and Panirghat (Sharonkhola). The dense populations of Hogla (*Typha aungustata*) might be indicative of heavily sedimented sloping sites as observed in Panirghat (Sharonkhola) and at the site near Sharonkhola Range Office. The dense populations of Kash (*Saccharum spontaneum*), Shon (*Imperata cylindrica*), Jhanjhani (*Crotalaria saltiana*) with scattered clumps of other few sedges were found to be mixed with some scattered individuals of Gewa (*Excoecaria agallocha*) but not within their population as at Deemyer Char and at the sampling area near the Jamtala Watch Tower beside the south bank of Jamtala Khal. Therefore, these fresh water species might have a tendency to migrate towards different habitats, at which normally they don't grow.

Noticeably very healthy individuals of Hargoza (*Acanthus ilicifolius*) as observed in Pakhir Char and Deemyer Char might be indicative of the new, healthy and promising plant diversity of less richness. Dense populations of healthy Hargoza (*Acanthus ilicifolius*) and Keya (*Pandanus foetidus*) might be indicative of slightly

Table 6. List of undergrowth species observed in Sundarbans mangrove ecosystem.

Sl.No	Local name	Scientific name	Family name	Habitat Preference
1.	Abetee	<i>Flagellaria indica</i>	Flagillariaceae	Elevated habitat with dry/less clayey mature soil
2.	Angoorlata	<i>Vitis sp.</i>	Vitaceae	Raised, comparatively less clayey soil
3.	Assam lata	<i>Mikania cordata</i>	Compositae	Raised, mature soil
4.	Baila ghash	<i>Myristachya wightiana</i>	Gramineae	Newly sedimented sandy-loam or clayey soil
5.	Bawali lata	<i>Sarcolobus globosus</i>	Asclepiadaceae	Elevated habitat with dry or less clayey soil
6.	Bawali lata	<i>S. carinatus</i>	Asclepiadaceae	Elevated habitat with dry or less clayey soil
7.	Bet	<i>Calamus sp.</i>	Palmae	Raised habitat of mature soil
8.	Bhola	<i>Hibiscus tilliaceus</i>	Malvaceae	Shady or open, elevated habitat with dry or less clayey soil
9.	Buno dhan	<i>Oryza ruffipogon</i>	Gramineae	Newly accreted land
10.	Chechra	<i>Scirpus articulatus</i>	Cyperaceae	Open depressed habitat with heavily clayey soil
11.	Chitka lata	<i>Flueggia virosa</i>	Euphorbiaceae	Raised habitat
12.	Choita boroi	<i>Salacia sp.</i>	Rhamnaceae	Elevated dry or less clayey soil
13.	Dhanshi	<i>Porterasia coarctata</i>	Gramineae	Newly accreted sandy or clayey habitat
14.	Dhekia lata	<i>Stenoclaena palustris</i>	Pteidophyte	Elevated, mature soil of old forests
15.	Gang lata	<i>Ipomoea biloba</i>	Convolvulaceae	Dry, sandy soil, dunes
16.	Ghaopatta	<i>Stephania japonica</i>	Menispermaceae	Raised, dry or less clayey soil
17.	Gila lata	<i>Entada pursaetha</i>	Leguminosae	Elevated, mature soil of healthy old forests
18.	Golpata	<i>Nypa fruticans</i>	Palmae	Especially river bank with clayey slopy soil
19.	Hargoza	<i>Acanthus ilicifolius</i>	Acanthaceae	Raised habitat with moderately clayey and sedimented soil
20.	Hental	<i>Phoenix paludosa</i>	Palmae	Sandy or less clayey, raised habitat, especially beside the river bank
21.	Hogla	<i>Typha angustata</i>	Typhaceae	Heavily clayey sedimented slopy site
22.	Horma ghash	<i>Hemarthria sp.</i>	Gramineae	Clayey habitat
23.	Hurmuri	<i>Sapium indicum</i>	Euphorbiaceae	Elevated dry/less clayey soil
24.	Jhonjhoni (pink)	<i>Crotalaria sp.</i>	Leguminosae	Raised, dry habitat with sandy soil

(Contd.)

Table 6. List of undergrowth species observed in Sundarbans mangrove ecosystem (Contd.).

25.	Jhonjhoni (yellow)	<i>Crotalaria saltiana</i>	Leguminosae	Raised, dry habitat with sandy soil
26.	Kalia lata	<i>Derris trifoliata</i>	Leguminosae	Elevated habitat with loamy or sandy-loam soil
27.	Kash	<i>Saccharum spontaneum</i>	Gramineae	Raised, dry habitat with sandy soil
28.	Keya	<i>Pandanus foetidus</i>	Pandanaceae	Raised habitat with moderately clayey and sedimented soil of fresh water zone
29.	Kholshi	<i>Aegiceras corniculata</i>	Myrsinaceae	Elevated, less clayey or sandy soil
30.	Kirpa	<i>Corallia brachenta</i>		Elevated, dry, sandy habitat
31.	Kutum lata	<i>Dalbergia spinosa</i>	Leguminosae	Clayey, open habitat
32.	Lata sundri	<i>Brownlowia lanceolata</i>	Tiliaceae	Clayey or sedimented soil, especially the bank side
33.	Malia ghash	<i>Cyperus</i> spp.	Cyperaceae	Clayey, open depressed sites
34.	Mamakala	<i>Fuergia</i> sp.		Raised, dry/less clayey soil
35.	Motmoti	<i>Clematis arborea</i>	Ranunculaceae	Elevated, dry habitat
36.	Nal khagra	<i>Phragmites karka</i>	Gramineae	Open, raised, less clayey habitat
37.	Nata/Natai	<i>Mucuna monosperma</i>	Leguminosae	Dry, elevated habitat
38.	Nona jhaw	<i>Tamarix indica</i>	Tamaricaceae	Raised habitat with clayey or dry soil
39.	Nuniagach	<i>Aegialitis rotundifolia</i>	Plumbaginaceae	Sandy or sandy-loam soil of raised habitat in more saline zones
40.	Shingra	<i>Cynometra ramiflora</i>	Leguminosae	Mixed with forest trees at raised, clayey soil in comparatively fresh water zones
41.	Shon	<i>Imperata cylindrica</i>	Gramineae	Elevated, sandy-dry soil
42.	Tambul Kata	<i>Dalbergia</i> sp.	Leguminosae	Raised habitat with clayey or dry soil
43.	Tiger fern	<i>Acrostichum aureum</i>	Pteridophyte	Elevated, open, dry or clayey soil
44.	Vhat	<i>Clerodendron inerme</i>	Verbenaceae	Comparatively dry or less clayey soil

depressed to raised habitats with moderately clayey and sedimented soil (Plate 21), as observed in some of the visited sites. The localized and continuous distribution of the healthy individuals of Hargoza (*Acanthus ilicifolius*) and Nona Jhau (*Tamarix indica*) following the dense populations of Dhanshi (*Porteresia coarctata*) observed in Tear Char might be indicative of the new, healthy and

promising mangrove plant diversity. As observed in few sites, the dense populations of Hargoza (*Acanthus ilicifolius*) and Kalia Lata (*Derris trifoliata*) along with Angoor Lata (*Vitis* sp.) and Chhitki Lata (*Flueggia virosa*) might be indicative of suitable habitats of most of the mangrove tree species. Mature populations of Bhola (*Hibiscus tiliaceous*) might be used as an indicator for shady sites, not favorable for the growth of almost all undergrowth species, except Keya (*Pandanus foetidus*), and also for the dry and elevated sites of the less clayey soil, suitable for Sundri or Sundri-Gewa dominated forest, as observed in Mirgamari, Panirghat (Sharonkhola) and Kotka.

Individuals of Hental (*Phoenix paludosa*) were found to be indicators for raised, less clayey sites and for maturing aspect of soil (Plate 16) instead of heavy sedimentation as observed in many of the visited sites. The poor growth of Hental (*Phoenix paludosa*) forming scattered clumps, as observed in the sampling areas of most of the sites in mature mangrove areas, may be indicative of the raised and less sedimented sites inside the mangrove forests, as well as the healthy and frequent growth of their individuals forming small dense populations, as observed in the neighboring canal areas of Jongra Beel, Mirgamari and Sharonkhola, may be indicative of the heavily sedimented sites of fresh water zone. The clumps of Hental (*Phoenix paludosa*) composed of few tall and healthy or slender individuals, associated or not associated with the healthy individuals of Kalia Lata (*Derris trifoliata*) and stunted ones of Hargoza (*Acanthus ilicifolius*), might be indicative of the healthy plant diversity of mature mangrove forests, as observed in the fresh water as well as in less saline zones. In contrast, small to large population of Hental (*Phoenix paludosa*) composed of densely grown dwarf, ill-developed and slender individuals, as observed along the margins of most of the visited sites in high saline zones, might be indicative of poor plant diversity as well as sick health status of mature mangrove forests.

Individuals of Kalia Lata (*Derris trifoliata*) were found to be indicators for raised, less clayey sites and for maturing aspect of soil instead of heavy sedimentation

observed in most of the visited sites. Some associate species like Kalia Lata (*Derris trifoliata*), Angoor Lata (*Vitis* sp.) and Shingra (*Cynometra ramiflora*) might be indicative for the elevated and loamy or sandy-loam sites of forest ecosystems as observed in Sharonkhola, and Kotka. There is possible indication of these associate species similar to that indicated by the healthy individuals of Kalia Lata (*Derris trifoliata*) and Hental (*Phoenix paludosa*), especially for typical elevated habitats of forest ecosystem dominated by Sundri (*Heritiera fomes*), Gewa (*Excoecaria agallocha*) in fresh water zone. Very dense growth of Kalia Lata (*Derris trifoliata*) along with spectacular healthy individuals of Hargoza (*Acanthus ilicifolius*) might be indicative to the newly formed healthy mangrove forest, especially of Keora, of poor plant diversity as observed in Pakhir Char and Deemyer Char. The complex of Kalia Lata (*Derris trifoliata*), Angoor Lata (*Vitis* sp.), Tambul Kanta (*Dalbergia spinosa*), Golpata (*Nypa fruticans*) and Chhitki Lata (*Flueggia virosa*) might be indicative of the habitats covered by a thin layer of sediment and followed by a thick layer of humus-rich black or grayish-black colored (Plate 16) soft or compact soil, suitable for the formation of new healthy mangrove forests, as observed in some other sites.

Observation on undergrowths of Patakata indicated that the restricted or partial distribution of fresh water or less saline water loving species like Shingra (*Cynometra ramiflora*) and Keya (*Pandanus foetidus*), along with or without the associated ones like Amoor (*Amoora cuculata*) and Karanja (*Pongamia pinnata*) etc., followed by the gradual absence of their individuals and the continuous distribution of Kalia Lata (*Derris trifoliata*) might be indicative to the transitional zone of saline and non-saline mangrove forests with moderately healthier plant diversity.

The presence of Gila Lata (*Entada pursaetha*) and its luxuriant growth provides strong evidence for its inclusion as an indicator species. The complex of mature individuals of Gila Lata (*Entada pursaetha*) and Shingra (*Cynometra ramiflora*) might

be indicative to the old stage of healthy mangrove vegetation as observed at the sampling area near the north bank of Jamtala Khal of Kotka.

The frequent distribution of healthy Lata Sundri (*Brownlowia lanceolata*) and the scattered clusters of ill-developed or stunted Hental (*Phoenix paludosa*) might be indicative of the elevated habitats composed of compact loamy soil enriched in humus and covered by thin layer of slippery clay, suitable for the formation of Kakra (*Bruguiera gymnorhiza*) dominated forests, as observed in Hodda. The dense growth of healthy clumps of Tiger Fern/Hudo (*Achrosticum aureum*) may indicate the raised sites of fresh water and saline zones that are not accumulating tidal or rainwater. The remnants of certain undergrowth species found in the Goran (*Ceriops decandra*) dominated sites, such as the ill-developed individuals of Hental (*Phoenix paludosa*), Golpata (*Nypa fruticans*) and Hargoza (*Acanthus ilicifolius*) and the healthy individuals of Tiger Fern/Hudo (*Achrosticum aureum*), Kalia Lata



Plate-22. Indication of Golpata (*Nypa fruticans*) to heavily sedimented habitat.

(*Derris trifoliata*), with or without the association of Kholshi (*Aegiceras corniculata*) and Tambul Kanta (*Dalbergia spinosa*), might be indicative of the suitable habitats for the formation of *Ceriops decandra* (Goran) dominated monotypic forests, as well as for the mangrove ecosystem of high saline zones. It can be envisaged

that the healthy complex of undergrowth species like Shingra (*Cynometra ramiflora*), Kalia Lata (*Derris trifoliata*), Hental (*Phoenix paludosa*) and Bhola (*Hibiscus tiliaceus*), occasionally associated with Hargoza (*Acanthus ilicifolius*), Keya (*Pandanus foetidus*), Golpata (*Nypa fruticans*) (Plate 23-29) and Angoor Lata (*Vitis sp.*), might be indicative of the most suitable habitats for the formation of a typical mangrove forests ecosystem.

On the basis of field observation as well as study on the features of undergrowths, it can be concluded that the individuals or populations of Bhola (*Hibiscus tiliaceus*), Keya (*Pandanus foetidus*), Hental (*Phoenix paludosa*), Hargoza (*Acanthus ilicifolius*), Golpata (*Nypa fruticans*), Shingra (*Cynometra ramiflora*), Kalia Lata (*Derris trifoliata*) (Plate 23-29) and Angoor Lata (*Vitis* sp.), with or without the association of other species like Lata Sundri (*Brownlowia lanceolata*), Choita boroii (*Salacia chinensis*), Dhekia Lata (*Stenochlaena palustris*), Kutum Lata (*Caesalpinia crista*), Ghaopata (*Stephania* sp) or Nona Jhau (*Tamarix indica*) may be pin-pointed to serve as the indicator species for assessing the health status of mangrove ecosystem, such as for very healthy monotypic forest of Sundri (*Heritiera fomes*) as observed in the site near Terabeka Khal of Sharonkhola as well as of mixed forests of Sundri (*Heritiera fomes*), Gewa (*Excoecaria agallocha*) and Keora (*Sonneratia apetala*), as observed in Jongra Beel, Mirgamari and Sharonkhola. Simply Keya (*Pandanus foetidus*) (Plate 1, 16 & 17) and Bhola (*Hibiscus tiliaceus*) might be indicative of a typical healthy biodiversity in Sundarbans forests ecosystem. The healthy individuals of these indicator species, with good growth performances, forming small clumps to large populations may be useful to indicate the good health status as well as rich biodiversity of mangrove forest. On the otherhand, the scattered clumps to large populations, composed of stunted and slender individuals with poor growth performances, especially of Hental (*Phoenix paludosa*), Hargoza (*Acanthus ilicifolius*), Golpata (*Nypa fruticans*), Kalia Lata (*Derris trifoliata*) and Tiger Fern (*Acrostichum aureum*), with or without the association of Bawali Lata (*Sarcolobus globosus*), and the absence of Bhola (*Hibiscus tiliaceus*) and Keya (*Pandanus foetidus*), may be pin-pointed to be the indicators for ill health status as well as poor biodiversity of mangrove ecosystem.

It can also be concluded that the rich diversity of undergrowths of healthy individuals might be indicative of the healthy mangrove forest of low saline zone whereas the poor diversity of undergrowths, as well as their stunted growth might be indicative of the ill mangrove forest of high saline zones.

CHAPTER-6

6. RECOMMENDATIONS

Spatial data, coupled with ecological associations and environmental parameters such as salinity, freshwater flow and sedimentation load etc. reveal that a group of undergrowth indicator species viz. Bhola (*Hibiscus tiliaceus*), Keya (*Pandanus foetidus*), Hargoza (*Acanthus ilicifolius*), Hental (*Phoenix palludosa*), Golpata (*Nypa fruticans*), Shingra (*Cynometra ramiflora*), Angoor Lata (*Vitis sp.*), Kalia Lata (*Derris trifoliata*) and Tiger Fern (*Acrostichum aureum*) (Table-7 and Plates 23-29) should be monitored in terms of certain qualitative characters (Table-8) for the assessment of the health status of the Sundarban Mangrove Ecosystem. Among these indicator species, Bhola, Keya and Shingra and also the undergrowths, especially Dhekia Lata (*Stenochlaena palustris*), Malia Ghash (*Cyperus spp.*), Nal Khagra (*Phragmites karka*), and Hogla (*Typha angustata*) that are not envisaged as useful in terms of their quantitative characters, should also be monitored in terms of their presence or absence, as they are restricted in the comparatively healthy mangrove ecosystem of fresh water or low saline zones of Sundarban, which are also richer in biodiversity.



Plate 23. Bhola (*Hibiscus tiliaceus*), indicator for biodiversity of freshwater mangrove zone.

Table-7. List of undergrowths finally selected as effective indicator species for the assessment of biodiversity health status in Sundarbans.

Sl. No.	Vernacular name	Scientific name	Family name	Distribution
1.	Bhola	<i>Hibiscus tiliaceous</i>	Malvaceae	Non-haline and Oligohaline zones
2.	Hental	<i>Phoenix paludosa</i>	Palmae	All zones
3.	Keya	<i>Pandanus foetidus</i>	Pandanaceae	Non-haline and Oligohaline zones
4.	Tiger fern/Hudo	<i>Achrostichum aureum</i>	Pteridophyte	Almost all zones
5.	Shingra	<i>Cynometra ramiflora</i>	Fabaceae	Non-haline and Oligohaline zones
6.	Hargoza	<i>Acanthus ilicifolius</i>	Acanthaceae	All zones
7.	Kalialata	<i>Derris trifoliata</i>	Fabaceae	All zones
8.	Angoorlata	<i>Vitis trifoliata</i>	Vitaceae	All zones
9.	Golpata	<i>Nypa fruticans</i>	Palmae	All zones

For a better and more logical application, these species can be monitored for their population abundance, healthy growth and development in order to assess the health status of the Sundarban biodiversity. In addition to these, Kutum Lata (*Caesalpinia crista*), Lata Sundri (*Brownlowia lanceolata*), Ghaopata (*Stephania japonica*), Tambul Kanta (*Derris crista*), Kholshi (*Aegiceras corniculata*), and Nona Jhau (*Tamarix indica*) may also be monitored in terms of presence or absence as they were observed in restricted distribution in fresh/saline water zones for the corroborative information for the conclusive data to be used in health status assessment of Sundarbans biodiversity.



Plate 24. Ill-developed Hental (*Phoenix paludosa*), indicator of sick biodiversity in high saline mangrove zone.

Preliminary observations on the qualitative and quantitative features of the indicator undergrowth species of the Sundarbans mangrove ecosystem on the basis of two 15 days field visits in two seasons only can not give conclusive data or evidence for the logical and authentic assessment of health status. However,



Plate-25. Hargoza (*Acanthus ilicifolius*), indicator for biodiversity of all mangrove zones.

certain quantitative features of different indicator undergrowth species (Table 8) might be useful for the very initial indication of the overall health status of biodiversity of Sundarbans mangrove forest ecosystem. The categories of health status (H=Healthy; MH=Moderately Healthy; UH=Unhealthy.) might be ascertained on the basis of field observation and diversity status of mangrove forest ecosystem. The ranges of quantitative data mentioned in the Table-8 are the averages of at least five records of each character. The range/s of quantitative data only for

one or two species may not be indicative due to which certain quantitative data on all selected indicator species should be considered for a more logical assessment of biodiversity health status. Beside this, the data should be collected only from the mature and comparatively healthier individuals of larger population of each species growing on typical habitats instead of young and ill-developed ones of smaller populations or scattered clumps formed on exceptional microhabitats. The quantitative data on Hental and Golpata should be collected only from the mature individuals growing on or beside the banks of canal or river.



Plate 26. Golpata (*Nypa fruticans*), indicator for biodiversity of almost all mangrove zones



Plate-27. Keya (*Pandanus foetidus*), indicator for biodiversity of freshwater mangrove zone.



Plate-28. Kalia lata (*Derris trifoliata*), indicator and invasive for biodiversity of all mangrove zones



Plate 29. Tiger fern/Hudo (*Acrosticum aureum*), indicator for biodiversity of almost all mangrove zones

Table-8. Quantitative characters of selected undergrowth indicator species useful for the assessment of biodiversity health status

Indicative Quantitative Characters	Name of Indicator Species									Health Status of Bio-diversity
	Bhola	Hargoza	Keya	Hental	Golpata	Shingra	Kalia Lata	Angoor Lata	Hudo	
										H
Height of main stem (cm)		140-200	80-200	300-390						MH
		80-130	70-74	150-250						UH
		>75	>65	>140						H
Width of main stem /bra. (cm)			13-24	13-20						MH
			8-11	10-12						UH
			>6	>8						H
Distance betw. main Br. (cm)	30-65					18-36				MH
	22-24					8-14				UH
	>20					>6				H
Internodal distance (cm)	6-9	6-11					6.5-12			MH
	3-5	2-5					4-6			UH
	>2	>1.5					>2.5			H
No. of leaf /plant			21-36	78-124	14-18					MH
			15-19	50-75	3-13					UH
			>13	>45	>2					H
No. of leaflet /leaf					106-175				20-30	MH
					90-100				12-15	UH
					>86					H
Breadth of lamina/ top leaflet (cm)	11-14	4-6					2.7-4			MH
	7-9	2-3					2.4-2.6			UH
	>5	>1.5					>2			H
Length of leaf /lamina (cm)		8-14	230-315	138-275	470-615			11-14	110-170	MH
		3-5	180-210	90-135	300-350			8-10	40-100	UH
		>2.5	>170	>86	>290			>6	>36	H
Breadth of side leaflet (cm)				1.5-2.0				2.9-4.4	2.4-5.5	MH
				1-1.4				2.5-2.6	2-2.2	UH
				>0.6				>2.2	>1.5	H
Breadth of top leaflet (cm)								3.4-5.2		MH
								3-3.1		UH
								>2.6		H
Length of side leaflet (cm)				36-48	135-140			4.6-6		MH
				28-35	85-100			4-4.3		UH
				>26	>83			>3.6		H
Distance betw. leaf scars (cm)				4-6						MH
				2-3						UH
				>1.8						H
Distance betw. leaflet (mm)					6-12				4.4-8.6	MH
					3-5				3-4	UH
					>2.8				2.8	H
Length of peteol. of top leaflet (cm)							1.4-1.8			MH
							>0.8			UH

NB: H=Healthy, MH=Moderately Healthy, UH=Unhealthy.

The quantitative data on each selected character should be taken from the maximum number of representatives from typically distributed range of populations and should also ensure that the measurements are taken from the comparable organs, as well as from the same age group of the individuals.

The ranges of the quantitative data on the initially identified undergrowth indicator species mentioned in the Table-8 should be checked in each season for several years before their final assessment and prediction in the field. For this purpose, extensive field explorations during each season are needed in order to get corroborative evidences both in connection with the final selection of indicator species and the ranges of their certain quantitative data in order to assess the biodiversity health status of the ecosystem/vegetation. The available quantitative data analysis especially for some of the initially identified indicator species like Hargoza, Hental, Golpata, Keya, Bhola and Angoor Lata etc. can be used to predict the health status (as unhealthy, moderately healthy and healthy) of the biodiversity or ecosystem of Sundarban Mangrove Forests. Moreover, the species useful in terms of certain quantitative data should be monitored annually for several years in terms of their biodiversity trend index (BTI), biodiversity status index (BSI) and biodiversity knowledge index (BKI) so as to develop an early warning system for restoration/conservation measures to be adopted.

Whether as corroborative or as partial evidences, the growth performances and productivity or biomass production by both of the indicators and other mangrove plant groups per standard unit area, preferably by placing a few permanent quadrats should also be monitored and analyzed for more logical assessment of health status of mangrove forest ecosystem. Basic research should be accomplished for ascertaining the criteria for classifying health status of mangrove forest ecosystem.

CHAPTER-7

7. REFERENCES

- Braun-Blanquet, J. 1932. Plant Sociology. The Study of Plant Communities (Translaid and edited by G.D. Fuller and H.C. Conrad). McGraw Hill Book Co. Inc., New York.
- Hussain, Z. and Acharya, G. (Eds.) 1994. Mangroves of the Sundarbans Volume two: Bangladesh. IUCN- The World Conservation Union, Gland, Switzerland
- Kent, M. and Coker, P. 1992. Vegetation description and analysis. John Wiley & Sons Ltd. Baffins Lane, Chichester, England. pp. 96-104.
- Karim, A. 1988. Environmental factors and the distribution of mangroves in Sundarbans with special references to *Heritiera fomes*. Buch-Ham. Ph.D. thesis (unpublished). University of Calcutta. 222 pp.
- Rapport, D.J. 1989. What Constitutes Ecosystem Health? Perspectives in Medical Biology. pp. 120-133.
- Raunkiaer, C. 1934. The Life-form of Plant and Statistical Plant Geography. Clarendon Press, Oxford, U.K.

FOR EXPERT BIODIVERSITY CONSULTANT (UNDERGROWTH ECOLOGY & FLORAL CALENDAR)

Duties

Expert Biodiversity Consultants will be responsible for the selection of indicators, the number of sampling sites to be considered for specific biodiversity surveys, and for the methodologies to be implemented during the survey, as well as the periodicity of the monitoring to take account of relevant natural cycles. Statistical validity regarding the number of samples and data will be responsibility of the individual expert. A map showing the approximate locations of the sampling sites along with the GPS co-ordinates need to be submitted and the sampling sites be marked on the ground for locating the exact point/s.

Individual Expert Biodiversity Consultants will submit, their detailed methodologies to IUCNB for scrutiny. Expert Biodiversity Consultants will work in close association with the other national and/or international experts, under the supervision of the Team Leader. The duties of the experts will include, but not be limited to, the following.

- *Collect, measure or note the relevant data parameters, of the given community from each of the sampling sites using the best available methodology for the given type of work.*
- *take the lead and be responsible for determining the parameters to be measured/noted/sampled so that the data collected never fails to achieve the goal to priorities the sensitivity of the species of the given community, towards measurements of biodiversity health and/or for developing the indicator/s*
- *Provide training in the given methodology, all ecological aspects of the indicators, and any other relevant knowledge, to the Project resource Biologists accompanying them on their two field trips to the SRE.*

- *While identifying threatened species, indicator or sensitive species, alien invasive species, microhabitats and/or others as he thinks necessary, develop their linkages with other communities inhabiting the given site/habitat.*
- *During the process, develop a list of species found in the given sampling site, including the abundance and threatened category of each of them.*
- *Assist in determining the threats with respect to biodiversity of the Sundarbans Reserve Forests.*
- *Contribute in identifying ecological biodiversity-rich sites, microhabitats, ecological zones and indicator species, especially in connection with thematic mapping.*
- *Analyse and interpret the data collected from the sampling sites, develop the indicator oriented linkage inferences/conclusions and prepare the required report on the assignment.*
- *Contribute in the preparation of the initial and final report on the biodiversity health status of the Sundarbans.*
- *Contribute in developing the training modules.*
- *Describe the biophysical condition of the sampling sites incorporating habitat description, mapping, sketches, etc.*
- *Perform any other activity as required, in the interest of the IUCNB assignment, under the directives of the Sr. Biodiversity Specialist or the Team Leader.*

The expert Biodiversity Consultants will undertake two trips to the Sundarbans- one in the wet season and the other in dry season- collecting data using the agreed methodology to incorporate the seasonal impacts, if any, in their studies. They will each submit an interim report after the first visit, while the final draft will be due immediately after their second visit. The raw data will be submitted to IUCNB along with soft hard copies of each report.

ANNEXURES

Annexure-1. List of species observed in the visited sites of Sundarbans mangrove ecosystem.

Sl. No.	Local name	Scientific name	Family name
1.	Abetee	<i>Flagellaria indica</i>	Flagillariaceae
2.	Amoor	<i>Amoora cuculata</i>	Meliaceae
3.	Angurlata/ Mormori lata	<i>Vitis</i> sp.	Vitaceae
4.	Assam lata	<i>Mikania cordata</i>	Compositae
5.	Baila ghash	<i>Myristachya wightiana</i>	Gramineae
6.	Bain (kala)	<i>Avicennia officinalis</i>	Aviceniaceae
7.	Bain (morich)	<i>Avicennia alba</i>	Aviceniaceae
8.	Bawali lata	<i>Sarcolobus globosus</i>	Asclepiadaceae
9.	Bawali lata	<i>S. carinatus</i>	Asclepiadaceae
10.	Beet	<i>Calamus</i> sp.	Palmae
11.	Bhatkathi	<i>Bruguiera perviflora</i>	Rhizophoraceae
12.	Bolla	<i>Hibiscus tilliaceus</i>	Malvaceae
13.	Buno alu	<i>Dioscoria</i> sp.	Dioscoriaceae
14.	Buno dhan	<i>Oryza ruffipogon</i>	Gramineae
15.	Chesra	<i>Scirpus articulatus</i>	Cyperaceae
16.	Chotta boroi	<i>Salacia chinensis</i>	Rhamnaceae
17.	Choyla	<i>Sonneratia caseolaris</i>	Sonneratiaceae
18.	<i>Cyperus</i> sp.	<i>Cyperus</i> sp.	Cyperaceae
19.	Dhanshi	<i>Porterasia coarctata</i>	Gramineae
20.	Dhekia lata	<i>Stenoclaena palustris</i>	Pteidophyte
21.	Dumur	<i>Ficus</i> sp.	Moraceae
22.	Gang lata	<i>Ipomoea biloba</i>	Convolvulaceae
23.	Gewa	<i>Excoecaria agallocha</i>	Euphorbiaceae
24.	Ghaopatta	<i>Stephania japonica</i>	Menispermaceae
25.	Ghas ?	<i>Pseudoraphis</i>	Gramineae
26.	Ghenchu	<i>Aponogeton</i> sp.	Alismataceae
27.	Ghila lata	<i>Entada pursaetha</i>	Leguminosae
28.	Golpatta	<i>Nypa fruticans</i>	Palmae
29.	Goran	<i>Ceriops decandra</i>	Rhizophoraceae
30.	Goroshun	<i>Crinum</i> sp.	Liliaceae
31.	Hargoza	<i>Acanthus ilicifolius</i>	Acanthaceae
32.	Hental	<i>Phoenix paludosa</i>	Palmae
33.	Hogla	<i>Typha angustata</i>	Typhaceae
34.	Horma ghash	<i>Hemarthria</i> sp.	Gramineae
35.	Hurmuri	<i>Sapium indicum</i>	Euphorbiaceae
36.	Jam	<i>Syzygium fruticosum</i>	Myrtaceae

(Contd.)

Annexure-1. List of species observed in the visited sites of Sundarbans mangrove ecosystem (Contd.)

37.	Jhana	<i>Rhizophora mucronata</i>	Rhizophoraceae
38.	Jhonjhoni (pink)	<i>Crotalaria</i> sp.	Leguminosae
39.	Jhonjhoni/Chhagal-boti (yellow)	<i>Crotalaria saltiana</i>	Leguminosae
40.	Jika	<i>Lannea cormandelica</i>	Anacardiaceae
41.	Kalia lata	<i>Derris trifoliata</i>	Leguminosae
42.	Kankra	<i>Bruguiera gymnorhiza</i>	Rhizophoraceae
43.	Kankra	<i>Bruguiera</i> sp.	Rhizophoraceae
44.	Kash	<i>Saccharum spontaneum</i>	Gramineae
45.	Kewra	<i>Sonneratia apetala</i>	Sonneratiaceae
46.	Keya	<i>Pandanus foetidus</i>	Pandanaceae
47.	Kholshi	<i>Aegiceras corniculata</i>	Myrsinaceae
48.	Kirpa	<i>Carallia brachiata</i>	Rhizophoraceae
49.	Koroi	<i>Albizia procera</i>	Leguminosae
50.	Koronja	<i>Pongamia pinnata</i>	Liguminosae
51.	Kukshim	<i>Atylosia</i> sp.	Leguminosae
52.	Kutum lata	<i>Dalbergia spinosa</i>	Leguminosae
53.	Lata sundari	<i>Brownlowia lanceolata</i>	Tiliaceae
54.	Malia ghash	<i>Cyperus tagetiformis</i> <i>C. exaltata</i> <i>C. malacensis</i>	Cyperaceae
55.	Mamakala	<i>Coccinea cordifolia</i>	Cucurbitaceae
56.	Motmoti	<i>Clematis arborea</i>	Ranunculaceae
57.	Nal khagra	<i>Phragmites khagra</i>	Gramineae
58.	Nata/natai	<i>Mucuna monosperma</i>	Leguminosae
59.	Nona jhaw	<i>Tamarix indica</i>	Tamaricaceae
60.	Nuniagach	<i>Aegialitis rotundifolia</i>	Plumbaginaceae
61.	Ghash	<i>Paspalum</i> sp.	Gramineae
62.	Passur	<i>Xylocarpus mekongensis</i>	Meliaceae
63.	Sharna lata (green)	<i>Cuscuta</i> sp.	Cuscutaceae
64.	Shingra	<i>Cynometra ramiflora</i>	Leguminosae
65.	Shon	<i>Imperata cylindrica</i>	Gramineae
66.	Sundari	<i>Heritiera fomes</i>	Meliaceae
67.	Tambul kata	<i>Derris crista</i>	Leguminosae
68.	Tiger fern	<i>Acrostichum aureum</i>	Pteridophyte
69.	Vhat	<i>Clerodendron inerme</i>	Verbenaceae

Annexure-2. Data collection format for the quadrat on undergrowth species.**Name of the site:**

Sl. No.	Name of the species	Local name	Habit	No. of individuals/Quadrat						Habitat/site	Ecological factors	Association	Population distribution (visual)	Ecological function
				Q1	Q2	Q3	Q4	Q5	Q6					

Annexure-3.1. Specific data collection format for **Bola** (*Hibiscus tiliaceous*).

Date	Name of the site	GPS	Forest type	No. of individuals /Quadrat	Width of main stem/branch	Distance between the branch	Internodal length	Petiole length	Leaf blade length	Leaf blade breadth

Annexure-3.2. Specific data collection format for **Hental** (*Phoenix paludosa*).

Date	Name of the site	GPS	Forest type	No. of indiv./ Quadrat	No. of indiv. /clamp	Height of the plant	Width of stem	Distance between leaf scars	Leaf length	Leaf breadth	Leaflet length	Leaflet breadth	No. of leaflet

Annexure-3.3. Specific data collection format for **Keya** (*Pandanus foetidus*).

Date	Name of the site	GPS	Forest type	No. of individuals /Quadrat	Height of the plant	Width of main stem/branch	No. of leaf /individual	Petiole length	Leaf length	Leaf breadth

Annexure-3.4. Specific data collection format for **Tiger fern/Hudo** (*Achrostichum aureum*).

Date	Name of the site	GPS	Forest type	No. of individ. /Quadrat	No. of individ. /clamp	Height of the plant	No. of leaf /individual	Leaf length	Leaflet length	Leaflet breadth	No. of leaflet

Annexure-3.5. Specific data collection format for **Shingra** (*Cynometra ramiflora*).

Date	Name of the site	GPS	Forest type	No. of individ./ Quadrat	Height of the plant	Width of main stem	Distance between branch	Internodal distance	Leaf length	Length of lamina		Breadth of lamina	
										Top	Side	Top	Side

Annexure-3.6. Specific data collection format for *Hargoza (Acanthus ilicifolius)*.

Date	Name of the site	GPS	Forest type	No. of individ./ Quadrat	No. of individ./ clamp	Height of the plant	Width of main stem	Internodal distance	No. of leaf /individual	Petiole length	Leaf length	Leaf breadth

Annexure-3.7. Specific data collection format for *Kalialata (Derris trifoliata)*.

Date	Name of the site	GPS	Forest type	No. of individ./ Quadrat	Distance between branch	Internodal distance	Leaf length	Length of petiole		Length of lamina		Breadth of lamina	
								Top	Side	Top	Side	Top	Side

Annexure-3.8. Specific data collection format for *Angurlata (Vitis trifoliata)*.

Date	Name of the site	GPS	Forest type	No. of individuals /Quadrat	Distance between branch	Internodal distance	Leaf length	Length of petiole		Length of lamina		Breadth of lamina	
								Top	Side	Top	Side	Top	Side

Annexure-3.9. Specific data collection format for *Golpata (Nypa fruticans)*.

Date	Name of the site	GPS	Forest type	No. of individ./ Quadrat	No. of individ./ clamp	Height of the plant	Width of leaf base	Leaf length	Leaflet distance	Leaflet length	Leaflet breadth	No. of leaflet

Annexure-4. Data collection format for geographical location and ecological parameters
Name of the site:

GPS-Coordinates	Forest type	Light	Humidity	Temperature	Water pH	Salinity

Annexure-5. Phenological data collection format for different species.

Sl.No	Name of undergrowth species	Phenological status		
		Flowering time	Fruiting time	Vegetative phase

Data analysis

Annexure-6a. Shannon diversity index for the undergrowth species in Sundri-Poshur-Kankra forest at Jangra beel during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Bhola	3.2	0.2025	-1.5969	-0.3234	2.0846
Angur lata	1.0	0.0633	-2.7600	-0.1747	
Kalia lata	1.2	0.0759	-2.5777	-0.1956	
Hargoza	1.9	0.1203	-2.1182	-0.2548	
Keya	2.7	0.1709	-1.7668	-0.3019	
Dhekia lata	3.3	0.2089	-1.5661	-0.3272	
Shingra	0.2	0.0127	-4.3694	-0.0555	
Abetee	0.9	0.0570	-2.8654	-0.1633	
Tiger fern	0.9	0.0570	-2.8654	-0.1633	
Nona jhau	0.4	0.0253	-3.6763	-0.0930	
Kutum lata	0.1	0.0063	-5.0625	-0.0319	

Annexure-6b. Shannon diversity index for the undergrowth species at Jongra beel during winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Bhola	1.63	0.153	-1.876	-0.287	2.038
Shingra	1.38	0.130	-2.043	-0.265	
Kalia lata	2.00	0.188	-1.671	-0.314	
Angur lata	1.13	0.106	-2.242	-0.238	
Hental	1.25	0.117	-2.141	-0.250	
Keya	1.50	0.141	-1.959	-0.276	
Tiger fern	0.75	0.070	-2.652	-0.186	
Hargoza	1.00	0.094	-2.365	-0.222	
	10.64			-2.038	

Annexure-7a. Shannon diversity index for the undergrowth species in Sundri-Kankra-Bain forest at **Mirgamari** (Poramahal) during rainy season.

Local name	ni	pi	Ln pi	Pi ln pi	- Σ pi ln pi
Bhola	2.55	0.0830	-2.4891	-0.2066	1.5949
Angur lata	0.91	0.0296	-3.5196	-0.1042	
Kalia lata	1.73	0.0563	-2.8771	-0.1620	
Hargoza	8.09	0.2633	-1.3346	-0.3514	
Keya	1.64	0.0534	-2.9305	-0.1565	
Dhekia lata	13.27	0.4318	-0.8397	-0.3626	
Shingra	2.00	0.0651	-2.7321	-0.1779	
Gila lata	0.27	0.0088	-4.7346	-0.0417	
Abetee	0.18	0.0059	-5.1400	-0.0303	
Choitta boroi	0.09	0.0029	-5.8332	-0.0017	

Annexure-7b. Shannon diversity index for the undergrowth species at **Mirgamari** (Poramahal) during dry-winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Keya	6.14	0.222	-1.505	-0.331	1.979
Shingra	3.00	0.108	-2.221	-0.240	
Hargoza	6.67	0.241	-1.422	-0.343	
Bhola	1.71	0.062	-2.783	-0.173	
Angur lata	1.00	0.036	-3.320	-0.119	
Abatee	0.71	0.026	-3.662	-0.095	
Dhokia lata	4.00	0.145	-1.934	-0.280	
Koromcha	0.14	0.005	-5.286	-0.026	
Kalia lata	1.00	0.036	-3.320	-0.119	
Hental	3.29	0.119	-2.129	-0.253	

Annexure-8a. Shannon diversity index for the undergrowth species in Sundri forest at **Terabecka** during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Bhola	0.50	0.0345	-3.3673	-0.1162	1.6953
Angur lata	0.60	0.0414	-3.1850	-0.1319	
Kalia lata	0.90	0.0621	-2.7795	-0.1726	
Hargoza	0.40	0.0276	-3.5904	-0.0991	
Tiger fern	0.20	0.0138	-4.2836	-0.0591	
Keya	0.50	0.0345	-3.3673	-0.1162	
Shingra	6.10	0.4207	-0.8659	-0.3643	
Hental	1.30	0.0897	-2.4118	-0.2163	
Assam lata	3.80	0.2621	-1.3391	-0.3510	
Abetee	0.10	0.0069	-4.9767	-0.0343	
Bawali lata	0.10	0.0069	-4.9767	-0.0343	

Annexure-8b. Shannon diversity index for the undergrowth species in Sundri forest at **Terabecka** during winter season.

Local name	ni	pi	ln pi	pi ln pi	- \sum pi ln pi
Bhola	1.13	0.053	-2.941	-0.156	1.951
Angur lata	1.50	0.070	-2.658	-0.186	
Kalia lata	0.63	0.029	-3.525	-0.102	
Hargoza	0.25	0.012	-4.031	-0.073	
Tiger fern	0.38	0.018	-4.031	-0.073	
Keya	2.25	0.105	-2.252	-0.236	
Shingra	5.63	0.263	-1.335	-0.351	
Hental	6.50	0.304	-1.192	-0.362	
Assam lata	2.00	0.093	-2.370	-0.220	
Abetee	0.38	0.018	-4.031	-0.073	
Bet	0.25	0.012	-4.450	-0.053	
Keya (leafy/dwarf)	0.50	0.023	-3.757	-0.086	

Annexure-9a. Shannon diversity index for the undergrowth species in Sundri-Gewa forest at **Panirghat** during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- \sum pi ln pi
Bhola	1.40	0.0927	-2.3782	-0.2205	1.7132
Angur lata	0.40	0.0265	-3.6310	-0.0962	
Kalia lata	3.40	0.2252	-1.4909	-0.3358	
Hargoza	0.70	0.0464	-3.0714	-0.1425	
Keya	4.50	0.2980	-1.2106	-0.3608	
Shingra	3.7	0.2450	-1.4064	-0.3446	
Chitka lata	0.20	0.0132	-4.3241	-0.0571	
Hental	0.80	0.0530	-2.9380	-0.1557	

Annexure-9b. Shannon diversity index for the undergrowth species in Sundri-Gewa forest at **Panirghat** during winter season.

Local name	ni	pi	Ln pi	Pi ln pi	- \sum pi ln pi
Hental	2.00	0.119	-2.125	-0.253	1.797
Shangira	6.75	0.403	-0.909	-0.366	
Keya	1.00	0.059	-2.818	-0.166	
Bhola	1.25	0.075	-2.595	-0.195	
Angurlata	0.50	0.030	-3.512	-0.105	
Kalialata	2.75	0.164	-1.807	-0.296	
Tiger fern	0.75	0.045	-3.106	-0.139	
Hargoza	0.25	0.015	-4.205	-0.063	
Golpata	1.50	0.089	-2.413	-0.214	

Annexure-10a. Shannon diversity index for the undergrowth species in Sundri-Gewa forest at **Dhabrivarani** during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Bhola	0.10	0.0049	-5.3279	-0.0261	1.5321
Dumur	0.10	0.0049	-5.3279	-0.0261	
Angur lata	1.00	0.0485	-3.0253	-0.1467	
Kalia lata	5.10	0.2475	-1.3961	-0.3455	
Hargoza	3.40	0.1650	-1.8015	-0.2973	
Keya	0.50	0.0243	-3.7184	-0.0904	
Shingra	2.30	0.1117	-2.1924	-0.2449	
Chitka lata	3.30	0.1602	-1.8314	-0.2934	
Hental	4.10	0.1990	-1.6143	-0.3212	
Assam lata	0.40	0.0194	-3.9416	-0.0765	
Bawali lata	0.30	0.0146	-4.2293	-0.0617	

Annexure-10b. Shannon diversity index for the undergrowth species in Sundri-Gewa forest at **Dhabrivarani** during winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Hental	2.75	0.180	-1.713	-0.308	1.880
Keya	1.25	0.082	-2.501	-0.205	
Shingra	1.50	0.098	-2.319	-0.227	
Bhola	0.25	0.016	-4.111	-0.066	
Assamlata	0.75	0.049	-3.012	-0.147	
Abatee	0.25	0.016	-4.111	0.066	
Kalialata	2.25	0.147	-1.913	-0.281	
Tiger fern	0.75	0.049	-3.012	-0.147	
Golpata	0.25	0.016	-4.111	0.066	
Hargoza	5.25	0.344	-1.066	-0.367	

Annexure-11. Shannon diversity index for the undergrowth species at Patakata during winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Shingra	3.33	0.171	-1.767	-0.302	1.875
Keya	1.17	0.060	-2.803	-0.169	
Kalia lata	5.17	0.265	-1.328	-0.352	
Moina lata	3.50	0.179	-1.718	-0.307	
Hental	2.50	0.128	-2.054	-0.228	
Hargoza	3.00	0.154	-1.872	-0.288	
Golpata	0.33	0.017	-4.079	-0.069	
Angur lata	0.33	0.017	-4.079	-0.069	
Koromcha	0.17	0.008	-4.742	-0.038	

Annexure-12. Shannon diversity index for the undergrowth species at Tear Char during winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Hargoza	6.14	0.623	-0.473	-0.294	1.123
Kalia lata	1.71	0.174	-1.751	-0.305	
Moina kata	0.71	0.072	-2.630	-0.189	
Hental	0.29	0.029	-3.525	-0.102	
Nona jhaw	1.00	0.102	-2.287	-0.233	

Annexure-13. Shannon diversity index for the undergrowth species at Pakhir Char during dry-winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Hargoza	6.00	0.448	-0.803	-0.360	1.538
Kalia lata	4.00	0.299	-1.209	-0.361	
Kholshi	0.40	0.030	-3.512	-0.105	
Tambul kata	0.02	0.015	-4.205	-0.063	
Chanda/moina lata	0.02	0.015	-4.205	-0.063	
Golpata	0.02	0.015	-4.205	-0.063	
Angur lata	0.60	0.045	-3.106	-0.140	
<i>Clerodendrum ennermi</i>	1.20	0.089	-2.413	-0.215	
Bhola	0.40	0.030	-3.512	-0.105	
Nona jhaw	0.02	0.015	-4.205	-0.063	

Annexure-14a. Shannon diversity index for the undergrowth species in Kewra –Gewa-Sundri forest at Dimeer Char during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Angur lata	2.00	0.121	-2.110	-0.255	1.728
Kalia lata	7.60	0.461	-0.775	-0.357	
Chitka lata	1.20	0.073	-2.621	-0.191	
Hargoza	5.5	0.333	-1.098	-0.366	
Kholshi	0.2	0.012	-4.413	-0.053	
Golpata	0.10	0.006	-5.106	-0.031	
Bhola	0.30	0.018	-4.007	-0.072	
<i>Ipomoea</i> sp.	0.50	0.030	-3.496	-0.105	
Jhanjhani	0.40	0.024	-3.720	-0.089	
Koromcha	0.20	0.012	-4.413	-0.053	
Nata	0.10	0.006	-5.106	-0.031	
Kutumkanta	0.20	0.012	-4.413	-0.053	

Annexure-14b. Shannon diversity index for the undergrowth species at Dimeer Char during winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Hargoza	3.00	0.187	-1.675	-0.313	1.820
Kalia lata	5.83	0.364	-1.010	-0.368	
Kholshi	0.17	0.011	-4.545	-0.050	
<i>Ipomoea</i> sp.	1.17	0.073	-2.616	-0.191	
Chanda/moina lata	0.17	0.011	-4.545	-0.050	
Golpata	0.17	0.011	-4.545	-0.050	
Angur lata	0.5	0.031	-3.466	-0.107	
Sharna lata	0.67	0.042	-3.174	-0.133	
Bhola	1.50	0.094	-2.368	-0.223	
Koromcha	0.33	0.021	-3.882	-0.082	
Kutum kata	0.33	0.021	-3.882	-0.082	
Assam lata	0.5	0.031	-3.466	-0.107	
Nata	0.17	0.011	-4.545	-0.050	
Motmoti	1.17	0.073	-2.616	-0.191	
Jhanjhani	0.33	0.021	-3.882	-0.082	

Annexure-15a. Shannon diversity index for the undergrowth species at Kotka during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Hental	3.14	0.247	-1.397	-0.345	1.677
Shingra	0.28	0.022	-3.814	-0.084	
Angur lata	0.28	0.022	-3.814	-0.084	
Tiger fern	4.71	0.371	-0.991	-0.368	
Kalia lata	0.86	0.068	-2.692	-0.183	
Ghila lata	0.28	0.022	-3.814	-0.084	
Bhola	0.43	0.034	-3.385	-0.115	
Hargoza	2.43	0.191	-1.653	-0.316	
Sundari lata	0.14	0.011	-4.507	-0.049	
Choita boroi	0.14	0.011	-4.507	-0.049	

Annexure-15b. Shannon diversity index for the undergrowth species at Kotka during winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Bhola	0.10	0.0128	-4.3567	-0.0558	1.5679
Angur lata	0.60	0.0769	-2.5649	-0.1972	
Kalia lata	0.40	0.0513	-2.9704	-0.1524	
Gila lata	0.30	0.0385	-3.2581	-0.1254	
Hargoza	2.80	0.3590	-1.0245	-0.3678	
Tiger fern	0.30	0.0385	-3.2581	-0.1254	
Shingra	0.50	0.0641	-2.7473	-0.1761	
Hental	2.80	0.3590	-1.0245	-0.3678	

Annexure-16. Shannon diversity index for the undergrowth species at Dhanshiddir Char during rainy season

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Kalia lata	8.45	0.6995	-0.3574	-0.2499	0.8734
Golpata	0.09	0.0075	-4.8995	-0.0367	
Chitka lata	0.18	0.0149	-4.2063	-0.0627	
Hargoza	0.18	0.0149	-4.2063	-0.0627	
Tiger fern	0.09	0.0075	-4.8995	-0.0367	
Shingra	2.82	0.2334	-1.4548	-0.3396	
Hental	0.27	0.0224	-3.8009	-0.0851	

Annexure-17. Shannon diversity index for the undergrowth species in Sundri-Gewa forest at KNM Collection Center during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Angur lata	0.21	0.0483	-3.0308	-0.1464	0.4961
Kalia lata	0.07	0.0161	-4.1294	-0.0665	
Bawali lata	0.07	0.0161	-4.1294	-0.0665	
Hargoza	0.14	0.0322	-3.4363	-0.1106	
Tiger fern	3.86	0.8874	-0.1195	-0.1061	

Annexure-18. Shannon diversity index for the undergrowth species in Gewa-Sundri-Poshur forest at Kewrabunia during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Kalia lata	2.00	0.2516	-1.3800	-0.3472	1.5634
Golpata	0.56	0.0704	-2.6530	-0.1868	
Gila lata	1.06	0.1333	-2.0149	-0.2686	
Hargoza	3.00	0.3774	-0.9746	-0.3678	
Tiger fern	0.11	0.0138	-4.2804	-0.0591	
Bawali lata	0.11	0.0138	-4.2804	-0.0591	
Hental	1.00	0.1396	-1.9688	-0.2748	

Annexure-19. Shannon diversity index for the undergrowth species in Gewa-Goran-Poshur forest at **Dobeki-Danokhali** during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Kalia lata	0.20	0.0308	-3.4812	-0.1072	0.8186
Angur lata	0.10	0.0154	-4.1744	-0.0643	
Chitka lata	0.20	0.0308	-3.4812	-0.1072	
Hargoza	0.90	0.1385	-1.977	-0.2738	
Tiger fern	5.00	0.7692	-0.2624	-0.2018	
Hental	0.10	0.0154	-4.1744	-0.0643	

Annexure-20. Shannon diversity index for the undergrowth species in Goran-Kewra-Poshur forest at **Dobeki** during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Kalia lata	0.58	0.5859	-0.5347	-0.3133	0.8828
Tambul kanta	0.33	0.3333	-1.0986	-0.3662	
Hargoza	0.08	0.0808	-2.5157	-0.2033	

Annexure-21. Shannon diversity index for the undergrowth species in Kankra-Gewa-Sundri-Poshur forest at **Hodda**.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Kalia lata	0.50	0.0559	-2.8848	-0.1613	1.3100
Bawali lata	0.17	0.0190	-3.9636	-0.0753	
Lata Sundri	4.22	0.4715	-0.7518	-0.3545	
Hargoza	1.78	0.1989	-1.6150	-0.3212	
Keya	0.11	0.0123	-4.3989	-0.0541	
Hental	2.17	0.2425	-1.4169	-0.3436	

Annexure-22a. Shannon diversity index for the undergrowth species in Gewa-Goran-Poshur forest at **Kalagachhia** during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Kalia lata	4.63	0.648	-0.433	-0.281	1.190
Hargoza	0.63	0.088	-2.428	-0.214	
Bawalilata	0.50	0.070	-2.659	-0.186	
Hental	0.75	0.105	-2.253	-0.237	
Golpata	0.25	0.035	-3.352	-0.117	
Kholshi	0.38	0.053	-2.933	-0.155	

Annexure-22b. Shannon diversity index for the undergrowth species in Gewa-Goran-Poshur forest at **Kalagachhia** during winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Hargoza	1.63	0.197	-1.624	-0.320	1.464
Kalia lata	4.00	0.484	-0.726	-0.351	
Bawali lata	0.88	0.106	-2.240	-0.237	
Kholshi	0.75	0.091	-2.400	-0.218	
Hental	0.63	0.076	-2.575	-0.196	
Golpata	0.38	0.046	-3.080	-0.142	

Annexure-23a. Shannon diversity index for the undergrowth species in Goran-Gewa forest at **Puspakathi** during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Hargoza	2.10	0.239	-1.433	-0.342	1.280
Hental	4.60	0.523	-0.649	-0.339	
Tiger fern	0.70	0.080	-2.531	-0.203	
Bawalilata	0.90	0.102	-2.280	-0.233	
Golpata	0.50	0.057	-2.868	-0.163	

Annexure-23b. Shannon diversity index for the undergrowth species at Puspakathi during winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Hargoza	6.13	0.537	-0.621	-0.334	1.288
Hental	1.75	0.153	-1.875	-0.287	
Golpata	1.38	0.121	-2.112	-0.256	
Tiger fern	0.75	0.066	-2.722	-0.180	
Kalia lata	1.00	0.088	-2.434	-0.214	
Bawali lata	0.40	0.003	-5.653	-0.017	

Annexure-24. Shannon diversity index for the undergrowth species in Goran-Sundri forest at Koikhali during rainy season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Kalia lata	10.92	0.6762	-0.3913	-0.2646	1.0326
Golpata	0.15	0.0093	-4.6790	-0.0435	
Hargoza	3.46	0.2142	-1.5407	-0.3300	
Tiger fern	1.08	0.0669	-2.7050	-0.1810	
Hental	0.54	0.0334	-3.398	-0.1135	

Annexure-25. Shannon diversity index for the undergrowth species at East Part of Raimangal River during winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Hargoza	9.90	0.508	-0.678	-0.344	1.559
Noonia	0.40	0.021	-3.887	-0.081	
Bawali lata	0.90	0.046	-3.076	-0.141	
Kalia lata	3.00	0.154	-1.872	-0.288	
Hental	1.50	0.077	-2.565	-0.197	
Golpata	1.40	0.072	-2.634	0.190	
Tiger fern	1.90	0.097	-2.329	-0.226	
Lata sundari	0.50	0.025	-3.664	-0.092	

Annexure-26 Shannon diversity index for the undergrowth species at **Dublar Char** during dry-winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Hargoza	5.63	0.412	-0.887	-0.365	1.820
Hental	3.25	0.238	-1.437	-0.342	
Bhola	0.75	0.055	-2.903	-0.160	
Angur lata	0.25	0.018	-4.001	-0.072	
Kalia lata	0.38	0.028	-3.583	-0.100	
Kholshi	0.13	0.009	-4.655	-0.042	
Koromcha	0.25	0.018	-4.001	-0.072	
Kutum kata	0.38	0.028	-3.583	-0.100	
Hurmori	0.13	0.009	-4.655	-0.042	
Cirpa	0.88	0.064	-2.743	-0.176	
Bawali lata	0.13	0.009	-4.655	-0.042	
<i>Cyperus</i> sp.	0.38	0.028	-3.583	-0.100	
<i>Clerodendrum ennermi</i>	1.13	0.083	-2.493	-0.207	

Annexure-27. Shannon diversity index for the undergrowth species at **Mandarbari** during winter season.

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Hargoza	4.00	0.249	-1.388	-0.346	1.609
Hental	1.25	0.078	-2.551	-0.199	
Kalia lata	1.13	0.070	-2.652	-0.186	
Tiger fern	7.25	0.452	-0.793	-0.359	
Bawali lata	0.88	0.055	-2.902	-0.160	
Tambul kata	0.63	0.039	-3.236	-0.126	
<i>Solanum xanthocarpim</i>	0.13	0.008	-4.815	-0.038	
Cirpa	0.38	0.024	-3.742	-0.090	
<i>Crotalaria</i> sp.	0.25	0.016	-4.161	-0.067	
Nata	0.13	0.008	-4.815	-0.038	

Annexure-28. Shannon diversity index for the undergrowth species at **Kalir Char** during winter season

Local name	ni	pi	ln pi	pi ln pi	- Σ pi ln pi
Hargoza	2.80	0.965	-0.035	-0.0339	0.148
Kalia lata	0.10	0.034	-3.367	-0.114	