Journal of Environment and Ecology
ISSN 2157-6092
2012, Vol. 3, No. 1

Biodiversity and Wild Fodder of Gorumara National Park in West Bengal, India

Fodder Plants and Habitat of Gorumara National Park

S. B. GHOSH
Associate Professor
Department of Botany, S. C. College
Habra – 743268, West Bengal, India
Tel: 91-943-386-8417/91-943-220-7896 E-mail: sbghosh_2003@msn.com

Received: April 1, 2012 Accepted: April 30, 2012 Published: December 1, 2012
doi:10.5296/jee.v3i1.1940 URL: http://dx.doi.org/10.5296/jee.v3i1.1940

Abstract

Gorumara National Park (GNP) in Duars, West Bengal, India, has an amazing biodiversity. Understanding of interactive factors was felt necessary. The undertaken programme included flowering plant identification, diversity indices calculation, faecal excreta examination, estimation of salinity of water courses and measurement of pH of soil and water. The floral Shannon's **H** at 6.38644 and Shannon's $\mathbf{E_H}$ at 0.9996, fodder species' **H** and $\mathbf{E_H}$ respectively at 2.6 - 4.06 and at 0.92 - 0.96, and mammalian species **H** and $\mathbf{E_H}$ in the ranges of 2.7-3.02 and 0.79-0.86, presented a sustainable ratio of flora and fauna. During winter, with low salt concentration of the flowing water courses (**TDS** 100 **ppm / L**; **EC** 167 **µS / cm^2**), the pachyderms tended to consume whole plant of grasses and herbs. During rains, with higher salt content of the same (450 **TDS**/750 **EC)**, they were found to consume tender foliage. Seeds retrieved from faecal matters demonstrated higher rate (70 - 90%) of germination. Eastern Himalayan Submontane Terai in Indo - Malaya Ecozone, with coordinates at 26 °40′ N and 88 °08′ E, temperature ambience around 9 °C - 30 °C, average RH at about 80 - 90%, average monthly rainfall of 1985 mm, ever flowing rivers and fascinating post-monsoon ecesis had been found to be the architect of this biosphere. Presence of salt – licks and water holes, herbivore – carnivore ratio, sapling production with seeds from faecal matters, economic stability and education of forest bound populace should be the key to tropical forest management.

Keywords: Biosphere factors, Fodder plants, Forest management, Habitat ecology, Indian wild herbivores

1. Introduction

The Gorumara National Park (GNP) in Duars, W. Bengal, India, has emerged one of the richest biodiversities in the region and in India as well. A Wild Life Sanctuary (WLS) since 1949 and a National Park (NP) since 1992, within an enclosure of merely 90 km^2, is harboring a rich heritage of floral and faunal diversities, unaffected over years. This research programme was carried out, from1994 to 2009, to find out the interactive factors responsible for the sustenance of this biodiversity and to 'show – case' GNP as a Model of *in situ* 'conservation of nature' in India.

Biodiversity conservation and forest management are now the major concern of all the responsible societies of the world. Pollution, Global Warming, emission from fossil fuel combustion, poverty and deforestation are the factors responsible for the destruction of our biodiversities and natural resources (Global Summit on Climate Change (Durban Summit, 2011- extending Kyoto Protocol till 2017, Kyoto 11th December, vide COP 7, 2001& Cancun Summit, COP 16, CMP 5, 2010).

A number of measures have been undertaken by the Government of India, with enactment of necessary laws and rules (The Environment (Protection) Act, 1986; The Forest (Conservation) Act/Rules, 1980/2003; The Wild Life (Protection) Act, 1972.), to conserve our natural habitats (Chowdhery & Hajra, 2000). It has been revealed that the proper afforestation planning (Ghosh, 1994) is central to all these conservation strategies.

Successful afforestation and other forest management programmes require a comprehensive census of the flora and fauna, detection of food habit of herbivores, identification of fodders (Ghosh, 1994), evaluation of mycorrhizal associations and other symbionts (Svrček, 1988; Chakraborty, 1991; Dirzo & Miranda1991; Arnold and Engelbrecht, 2007), detection of soil profile, detection of resources for water and salt supplementations, selection of plant propagules and determination of plantation method (Madhusudan, 2004). Evaluation of tree species in climax vegetation is very important. A tree species creates an ecological niche of its own (Stork, 1991; Andrea and Russell, 2005) and denudation of it may bring forth a cascade effect resulting in the defaunation of a biodiversity (Leigh, Wright, Herre, & Putz, 1993).

This is the second phase of the programme on 'Identification of Wild Fodders and Study of Biodiversity of Indian Sanctuaries' (Ghosh, 1994). Prerequisites for the enrichment and sustenance of the biodiversity in GNP have been determined and measures necessary for better forest management have been evaluated and enumerated.

2. Materials and Methods

2. 1 Field Work: Collection of Specimens, Samples and Information

2.1.1 Plant Specimens

Whole plant or Parts of flowering species, with emphasis to fodder species (consumed, in one form or other, by wild mammalian herbivores and birds), were collected from three very distinct ecotones (as Riverain Rolling Flood Land Forests or RFF, Riverine Riparian Forests or RRF & Sal Savannah Climax Forests or SCF) of eight major blocks of GNP (namely Dhupjhora, Gorumara, Jaldhaka, Medla Jhora, Neora, Murti, Shelkapara and Tondu). Collections were made on the bases of visual observations of grazing, grazing marks on plants coupled with hoof - marks/foot prints and on the bases of the reports from forest personnel.

2.1.1.1 Floral Diversity

Sampling of plant specimens (counting of species and number of individuals) were made from the test plot areas ($1m^2$ - $256m^2$; 5 continuous plots) in each specific ecotone (vide section 2.1.1), giving special emphasis to fodder species. To reveal occurrence of number of species and relative abundance of individuals, simple Quadrat method was followed. An average number of samples (species & individuals) from 3 plot areas in each ecotone in 8 block areas were considered. Species richness (***S***) and relative (proportionate) abundances of individuals (***Pi***) were taken into account for further determination of Species Diversity. The Diversity Indices of individual ecotones have been expressed and compared in terms of Shannon's index (**Shannon H**) and Simpson's index (**Simpson D**, which may be expressed as reciprocal of D as **1/D or as 1-D**), using the following formulae as,

Shannon's $H = -\sum_{i=1}^{S} Pi * \ln(Pi)$ and $E_H = \frac{H}{H_{max}} = \frac{H}{\ln S}$; **Simpson's** $D = \sum_{i=1}^{S} Pi^2$ and $E_D = \frac{D}{D_{max}} = D \times \frac{1}{S}$

Where **H** = Shannon diversity index, $\mathbf{P_i}$ = fraction of the entire population made up of species **I**, **S** = numbers of species encountered, ∑ = sum from species 1 to species S, **ln** is natural logarithm and **D** = Simpson's diversity index ($\mathbf{E_D}$ Simpson's equitability or evenness). Shannon's equitability ($\mathbf{E_H}$) can be calculated by dividing **H** by $\mathbf{H_{max}}$ (here $\mathbf{H_{max}}$= **lnS**). Equitability assumes a value between 0 and 1 with 1 being complete evenness. The species evenness or equitability was calculated and expressed in terms of Shannon $\mathbf{E_H}$ and was compared with same expression of Simpson $\mathbf{E_D}$ (Magurran 1988; Roth, Perfecto & Rathcke 1994; Rosenzweig 1995; Begon, Harper & Townsend 1996). The non-flowering plants were not considered for the present purpose.

2.1.2 Faunal Components

On the basis of intensive and comprehensive observations (1994-2009) of the movement of the mammalian species through the block areas (vide section 2.1.1.) in GNP and based on the reports from field workers and forest personnel, a list of the mammalian species of the fauna has been prepared with a field note on their food habit and feeding pattern. Certain members of the resident avian fauna (Ali & Ripley 1987; Das, 2009) and their food habit were also under observation to ascertain the origin of some bird-dropping samples that contain viable seeds of flowering plants.

2.1.2.1 Faunal Diversity

For present purpose of study, counting of only the mammalian species were made, on the bases of visual observation of their presence in any particular area and on the bases of pug marks, hoof marks, grazing marks and presence of faecal matters in the ecotones (vide section 2.1.1). The faunal Species Diversity (e.g. Shannon H) and Species Evenness (e.g. Shannon E_H) were calculated in the same way as stated in the section 2.1.1.1.

2.1.3 Faecal Matters

Bird-droppings and excrements of wild mammalian species were examined to ascertain their food habit (Storr 1961; Gaylard & Kerley 1997). Samples were collected (from October – June; sampling was not possible during Jul. - Sep. due to rain) separately and aseptically in screw capped plastic containers (25ml) with reference number tags.

2.1.4 Soil samples

Samples from different areas were collected in wide-mouth glass vials (20 ml) with ebonite screw cap. Samples were taken from all the three distinct ecotone of all major block areas (vide section 2.1.1) of GNP.

2.1.5 Water samples

Water samples from flowing and stagnant water courses were collected (from upto 60 cm deep only), throughout the year, in thoroughly cleaned (with the same sample water) mineral water bottles (500 ml) from different block areas of GNP.

2.1.6 Geographical Location and Climate information

Geographical coordinates of Gorumara N.P. were determined from the GPS through internet and from authentic maps (the Plate Nos. 99 & 105 of National Atlas of India 1975 – see Reference). Information on weather, in relation to humidity, temperature and rainfall, were gathered and compiled from various reports of Regional Meteorological Office, Jalpaiguri and from various Range Offices with continuous monitoring of the area.

2. 2 Laboratory Work: Analysis and Identification of Samples and Specimens

2.2.1 Plant Identification

Plants were identified by using various identification manuals, floras and keys (Prain 1903; Bor, 1973; Cronquist 1981; Roy 1984; Karthikeyan et al 1989; Sharma & Balakrishnan 1993*a*; Sharma et al 1993*b*; Sharma & Sanjappa1993*c*; Verma, Balakrishnan & Dixit 1993; Ghosh 1994; Hajra, Nair & Daniel 1997; Bhattacharya 1997; Singh 2000 *a*; Singh, Vohra & Singh 2000 *b*).

2.2.2 Examination of Faecal Matters

Slurry was prepared with dried (at 60^0 for 6hr) faecal matter (10% w/v) with lukewarm (45 ℃) solution of NaCl (0.1 M) and were examined under the scanning and light transmitted compound microscopes.

2.2.3 pH of Soil and Water

pH of the samples was measured in pH meter following usual method, calibrating against standard buffer solutions (pH 5.0 - 9.0 with citrate, citrate-phosphate, phosphate and phosphate-carbonate systems).

2.2.4 Salt Content of River Water

Salt content as a measure of Total Dissolved Salt (TDS) and its corresponding Electrical Conductivity/Resistance (EC) were determined with little modifications of certain standard methods (Weast 1978; Anderson, Cummings & Cummings 1994).

(a) **Gravimetric method** -The sample was filtered, 5 ml of each was taken in thin watch -glass and was dried at 60 ℃ for 8hr. The residual sediments were weighed to determine the 'Total Dissolved Salts' (expressed as % TDS w/v or more conventionally in ppm or mg/L units; may sometime be referred to as 'Total Dissolved Solids').

(b) **Electrometric method** - The sample was taken in beaker (200 ml in 250 ml beaker) and the 'Electrical Conductivity' (EC) of the fluid was measured using suitable electrodes ($1cm^2$ electrode terminals at 1cm space apart). EC or 'Electronic Conductance' is expressed in terms of 'micro Siemens per square centimeter' or $\mu S/cm^2$ units at 25 ℃, considering the temperature compensation factor @ 2.2 % per ℃, below 30 ℃ and in the temperature range of 20 ℃ - 30 ℃; The EC - TDS conversion is TDS ppm or mg/L = EC (µS/cm^2 at 25 ℃) X 0.6.

3. Results

3. 1 Constituents of Flora and Fauna

3.1.1 Flora

About 595 species of flowering plant species, including 75 fodder species (Tables 1 - 3), have so far been identified from GNP. Grasses (ca 43 species; Table-3) were everywhere with their larger varieties dominating in the RFF and RRF ecotones. Larger grass varieties were found to be growing luxuriantly on alluvial sandy - loam soil with pH from 6.0 to 7.4 while the smaller varieties of grasses demonstrated tolerance level over the pH range from 5.5 to 8.5. The dicotyledonous and non-grass monocotyledonous fodder have been found to be distributed mostly in the RRF and SCF ecotones (Section 2.1.1.).

3.1.2 Floral Diversity

With these 595 species of angiosperms, the workable data accounted for a very high Diversity Index value (**Shannon's H**) at 6.3864, in GNP as a whole. The species equitability or evenness (**Shannon's E_H**) value was around 0.9996 (near 1) and was therefore very even and well balanced. Out of 75 fodder species (Table 1 – 3; # 13 – ***Cynodon dactylon*** **(L.) Pers.** has not been considered because of unspecific preference by any herbivore), individual ecotone communities contained a maximum of 17 - 70 such species. The Diversity Indices (Shannon's **H**) in different ecotones stood between 2.6 to 4.06 (**Simpson's D** value from 0.92 to 0.98) and showed high magnitude of fodder species richness in GNP. The equitability or evenness index (Shannon's **E_H**) values varied from 0.92 to 0.96 (**Figures 1. & 2.**) showing complete evenness in the distribution of individuals (**Simpson's E_D** values were from 0.01 to 0.05) and heterogeneity in the fodder plant communities.

Table 1. Dicotyledonous Fodder Plants of GNP[1] found in RRF[2] and SCF[2] Ecotones

Taxonomy & Common Names	**Consumable Part & Consumer (serial # from Table 4 for mammals)**
Trees	
1. *Dillenia pentagyna* Roxb. Dilleniaceae. Tantari	Fr.* - Birds, & # 21,23,28 & herbivores
2. *Annona reticulata* Linn. Annonaceae. NonaAta	Fr. - Birds, & # 1-8, 21,26
3. *Shorea robusta* Gertn. f. Dipterocarpaceae. Sal	Fl.† & Fr. - # 1-8, 26, 29-31, 33
4. *Bombax ceiba* Linn. Bombacaceae. Simul	N‡ -Birds, fallen Fl. # 26, 29-31, 33
5. *Grewia asiatica* Linn. Tiliaceae. Phalsa	Fr. - Birds, # 1-8, 12, 21, 28-31
6. *Grewia tiliaefolia* Vahl. Tiliaceae. Olat	Fr. - As above
7. *Azadirachta indica* A. Juss. Meliaceae. Neem	Fr. – Birds, fallen Fr. # 26, 29-31
8. *Ziziphus mauritiana* Lamk. Rhamnaceae. Kool	Fr. - Birds, # 1-3, 26
9. *Mangifera indica* Linn. Anacardiaceae. Mango	Fr. Birds, herbivores, Sd. ¶# 1-3
10. *Syzygium cumini* (L.) Skeel. Myrtaceae. Jamun	Fr. - Birds, herbivores, 21, 23
11. *Syzygium jambos* (L.) Alst. Myrtaceae. Gulab Jamun	Fr. - As above
12. *Trema orientalis* (L.) Bl. Ulmaceae. Chikun	L § - # 26, 33; Fr. - Birds
13. *Ficus bengalensis* Linn. Moraceae. Bot	(For all ***Ficus*** sp.) L & B. ** # 26;
14. *F. cunia* Ham. Moraceae. Jagnadumur	fallen CSt. †† by # 29-31,33;
15. *F. hirta* Vahl. Moraceae. Bandumur	HInf. ‡‡ Birds, fallen ones
16. *F. hispida* Linn. f. Moraceae. Dumur	by other herbivores
17. *F. religiosa* Linn. Moraceae. Aswattha	
Herbs, Shrubs & Lianes	
18. *Tinospora cordifolia* (Willd.) Hook.f. & Thoms. Menispermaceae. Gulancha	L - # 26, 29-31
19. *Portulaca oleracea* Linn. Portulacaceae. Laniya	WP ¶¶- # 29-31
20. *Mikania scandens* Willd. Asteraceae.	WP - # 26, 29-31
21. *Amaranthus spinosus* Linn. Amaranthaceae. Kanta notey	WP - # 29-31
22. *Amaranthus viridis* Linn. Amaranthaceae. Bon notey	WP – As above
23. *Lantana camara* Linn. var. *aculeata* (L) Moldenke Verbenaceae. Lantana	Fr. - Birds
24. *Phyllanthus reticulatus Poir.* Euphorbiaceae.	Fr. – Birds; # 29-3

Table-1. Abbreviations: GNP[1]– Gorumara National Park; RRF[2] & SCF[2] – Ecotones -vide section 2.1.1. *Fruit; †Flower; ‡Nectar; ¶Seed; §Leaf;**Bark; ††Convolute stipule; ‡‡Hypanthodium Inflorescence; ¶¶Whole Plant

Table 2. Monocotyledonous Fodder Plants of GNP[1]

Taxonomy & Common Names	**Consumable Part, Consumer (Table 4 serial # for mammals) & Ecotones[2]**
25. *Alpinia Malaccensis* (Burn.f.)Rosc. Zingiberaceae Purundi	WP* & Rz.† - # 26 -28; RRF
26. *Alpinia nigra* (Gaertn.) Burtt. Zingiberaceae Jal Purundi	WP - as above; RRF
27. *Costus speciosus* (Koenig ex Retz.) Smith Zingiberaceae Keo	WP. - as above; RRF, SCF
28. *Dioscorea anguina* Roxb. Dioscoreaceae Mete alu	T‡ – # 26 & 28; SCF
29. *Dioscorea pentaphylla* Linn. Dioscoreaceae Kanta alu	T - as above; SCF
30. *Colocasia antiquorum* Schott. Araceae Kachu	Cor. ¶- # 28; RRF, SCF
31. *Phoenix silvestris* Roxb. Arecaceae Khejur	Fr. § – Birds; & # 1-8; fallen Fr. – # 23 & all herbivores; SCF
32. *Cyperus distans* Linn. f. Cyperaceae	Rz. - # 28; RRF, SCF
33. *Cyperus niveus* Retz. Cyperaceae	Rz. – as above; RRF, SCF

Table – 2. Abbreviations: 1 – Gorumara National Park; 2 - Ecotones (RRF & SCF) – vide section 2.1.1.; *Whole Plant; †Rhizome; ‡Tuber; ¶ Corm; §Fruit;

Table 3. The Fodder Grasses (Family: Poaceae or Gramineae) of GNP[1]

Names	Consumer (Table 4 serial #) & Ecotones[2]
1. *Alloteropsis cimicina* (Linn.) Stapf.	12, 29-33; RRF, SCF
2. *Apluda mutica* Linn.	26, 27, 33; RFF, RRF
3. *Arundinella bengalensis* (Spreng.) Druce.	26,27,32,33; RFF,RRF
4. *Arundinella decempedalis* (O. Ktze.) Jan.	26,27,33; RFF, RRF,SCF
5. *Arundinella setosa* Trin. Var. *setosa*.	26,27,29-33; RFF,RRF
6. *Arundo donax* Linn.	26,27,32,33;RFF, RRF
7. *Axonopus compressus* (Swartz.) P. Beauv.	12, 29-31,33;SCF
8. *Brachiaria ramosa* (Linn.) Stapf. var. *ramosa*	12, 29-31,33;RRF
9. *Capillipedium assimile* (Steud.) A.Camus.	12, 29-31,33; SCF
10. *Centotheca lappacea* (Linn.) Desv.	26,27 29-33; RRF
11. *Coix lachryma-jobi* Linn. Var. *stenocarpa* Stapf.	26,27,33; RRF, SCF
12. *Cymbopogon pendulus* (Nees & Steud.) Wats.	12, 29-33; SCF
13. *Cynodon dactylon* (L.) Pers.	Unspecified
14. *Desmostachya bipinnata* (Linn.) Stapf.	26,27,32,33;RRF,SCF
15. *Digitaria ciliaris* (Retz.) Koel.	12,29-31,33; SCF
16. *Digitaria longiflora* (Retz.) Pers.	12,29-31,33; SCF
17. *Digitaria sanguinalis (Linn.)* Scop.	12,29-31,33; SCF
18. *Eragrostis gangetica* (Roxb.) Steud.	12,29-31,33; SCF
19. *Eragrotis pilosa* (Linn.) P. Beauv.	12,29-31,33; SCF
20. *Eragrotis tenella* (Linn.)P.Beauv.exR.&S.	12,29-31,33; SCF
21. *Eulaliopsis binata* (Retz.) C. E. Hubb.	27, 29-31,33; RRF
22. *Hemarthria protensa* Steud.	12,29-31,33; RRF
23. *Imperata cylindrica* (Linn.) Raeuschel.	26,27,33; RFF, RRF, SCF
24. *Isachne miliacea* Roth. ex R. & S.	26,27,33; RRF
25. *Ischaemum barbatum* Retz.	26,27,33; RRF
26. *Oryza meyeriana* ssp. *granulata* (Nees & Arn. ex Hook.f.) Tateoka.	12,29-31; RRF, SCF
27. *Panicum auritum* Presl ex Nees.	12,29-31,33; RRF,SCF
28. *Panicum repens* Linn.	12,29-31,33; RRF, SCF
29. *Paspalum scrobiculatum* Linn. Var. *scrobiculatum*	12,29-31,33; SCF
30. *Pennisetum glaucum* (Linn.) R. Br.	12,29-31,33; SCF
31. *Phacelurus zea* (C.B. Clarke) W. B. Clayt.	26,27,29-33; RRF
32. *Polypogon fugax* Nees. ex Steud.	by All; RRF
33. *Polytoca digitata* (Linn. f.) Druce.	by All; RRF
34. *Rottboelia cochinchinensis (Lour.)* W. B. Clayt.	by All; RRF
35. *Saccharum arudinaceum* Retz.	26,27,33; RFF, RRF
36. *Sac. bengalense* Retz.	26,27,33; RFF, RRF
37. *Sac. longisetosum* (Anderss. ex Benth.) Narayanasw. ex Bor Var. *longisetosum*	26,27,33; RFF, RRF
38. *Sac. narenga* (Nees ex Steud.) Hack.	26,27,33; RFF, RRF
39. *Sac. spontaneum* Linn.	26,27,33; RFF, RRF
40. *Setaria barbata* (Lam.) Kunth.	26,27,33; RRF, SCF
41. *Setaria palmifolia* (Koen.) Stapf.	26,27,33; RRF, SCF
42. *Themeda arundinacea* (Roxb.) Ridl.	26,27,33; RFF, RRF
43. *Themeda caudata (Nees)* A. Camus.	26,27,33; RFF, RRF

Table – 3. 1– Gorumara National Park; 2 - Ecotones (RFF, RRF & SCF) – vide section 2.1.1.

3.1.3 Mammalian Fauna

A total of 33 mammalian species have been spotted in GNP and have been enlisted in the Table – 4, with nomenclatural citations and notes on their food habit (Sir Huxley, 1974; Israel, Sinclair & Grewal 1989; Wilson & Reeder, 2005).

3.1.4 Faunal Diversity

Diversity Indices (Shannon's H)of mammalian fauna, in the range of 2.7 - 3.02 (**Figure 2.**), indicated high degree of mammalian diversity (species richness) in GNP. With the Shannon's E_H value from 0.79 to 0.86, the mammalian fauna exhibited extreme evenness in their distribution and movement in GNP.

3.2 Plant Parts in Faecal matters

Faecal excreta of pachyderms most often contained large and stout rachis, rachilla, hard awn and brownish outer glumes of larger grasses (Table 3; # 3-6, 10, 11, 25, 35-39 & 42). The seeds of non-grass fodder (Tables 1 & 2) have been found in the faecal matters of birds, deer and elephants. Seeds retrieved from the faecal matters of non – ruminant herbivores and bird - droppings exhibited higher frequency of germination (70 - 90%) than those gathered from forest floor (10 – 40%). These seeds can be used for sapling production (Jones, Curran, Wright & Mack, 2008). Microscopic examinations revealed partial erosion and disintegration of outer coat of these seeds. The seeds recovered directly from plants or forest floor were smooth and intact. Seeds of ***Syzygium cumini* (L.) Skeel., *Syzygium jambos* (L.) Alst., *Grewia asiatica* Linn., *Grewia tiliaefolia* Vahl.** and ***Phoenix silvestris* Roxb.** have been found in the faecal matters of palm civet and golden jackal (Table 4), which are carnivores. Some faecal samples of the herbivorous Indian crested porcupine and wild boar even contained bone fragments.

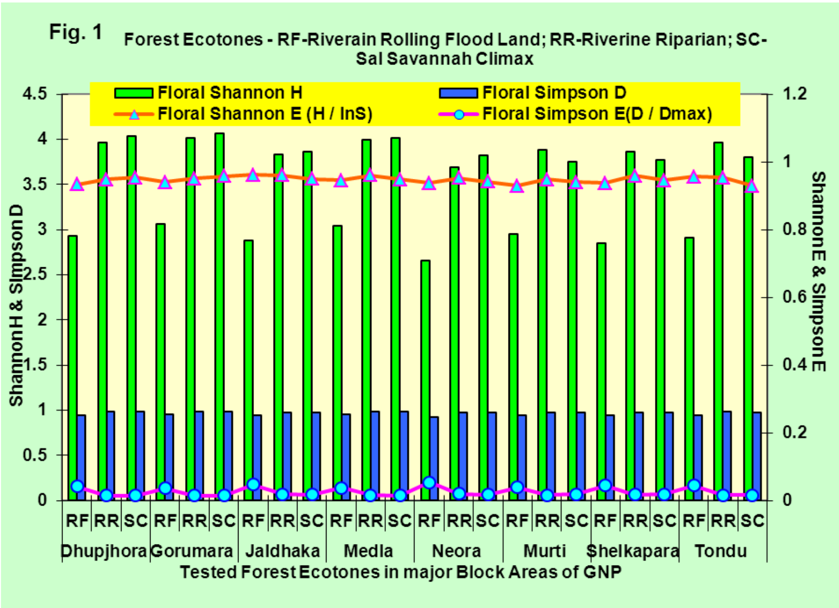

Figure 1. Diversity and Equitability Indices of Fodder Species in GNP.

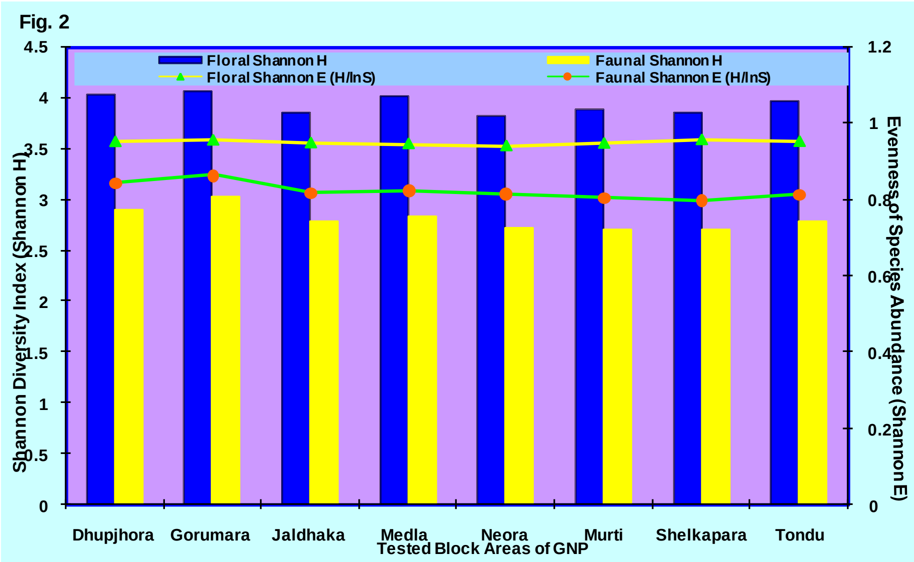

Figure 2. Variations in Diversity and Equitability of Fodder & Mammals in different blocks.

3. 3 pH of Samples

3.3.1 Soil

(a) Soil samples from the Riparian Forest Fringes and River Banks were in the pH range of 6.9 - 7.8; (b) Samples from the Savannah Grass Land in the low lying areas and from the flood plains of rivers, showed the range of pH from 6.5 to 7.6; (c) Upper Soil Layers (upto 20 cm - supporting grasses and herbs) from the Deciduous and Mixed Evergreen Climax Forest zones in the high land exhibited wide range of pH variations from 5.8 to 8.2.

3.3.2 Water

(a) Samples from Stagnant water, which were not replenished by rivers or streams, were in the pH range of 5.9 to 7.3; (b) Samples from Flowing Water Systems were in the pH zone of 7.1 to 8.8.

Journal of Environment and Ecology
ISSN 2157-6092
2012, Vol. 3, No. 1

Table 4. Food Habit and Habitat of Wild Mammals of GNP[1]

Taxonomy & Common Name	**Food Habit &Ecotone**[2]
1. ***Macaca assamensis*** **Cleland 1839. Cercopithecidae** Assam Macaque	PP*, eggs, chicks; SCF; RRF
2. ***Macaca mulatta*** **Zimm. 1780. Cercopithecidae** Rhesus Monkey	as above; SCF
3. ***Semnopithecus entellus*** **Dufresne 1797. Cercopithecidae** Indian Langur	as above; SCF; RRF
4. ***Ratufa indica*** **Erxleben 1777. Sciuridae / Ratufinae** Indian Giant Squirrel	PP, eggs, larvae; SCF
5. ***Funambulus*** **(*Funambulus* - Sub Genus)** ***palmarum*** **Linn. 1758. Sciuridae / Callosciurinae** Indian Palm Squirrel	PP; SCF
6. ***Funambulus*** **(*Prasadsciurus* - Sub Genus)** ***pennantii*** **Wroughton 1905. Sciuridae / Callosciurinae** Five Striped Palm Squirrel	as above; SCF
7. ***Callosciurus erythraeus*** **Pallas 1779. Sciuridae / Callosciurinae** Pallas's Squirrel	as above; SCF & RRF
8. ***Callosciurus pygerythrus*** **I. Geoffroy - Saint Hilaire 1833. Sciuridae / Callosciurinae** Orange Belly Irrawaddy Squirrel	as above; SCF & RRF
9. ***Bandicota bengalensis*** **Gray 1835. Muridae** Lesser Bandicoot Rat	Scavenger; SCF
10. ***Bandicota indica*** **Bechstein 1800. Muridae** Greater Bandicoot Rat	Scavenger; SCF & RRF
11. ***Hystrix*** **(*Hystrix* - Sub Genus)** ***indica*** **Kerr 1792. Hystricidae** Indian Crested Porcupine	Herbs, bones, larvae; SCF
12. ***Caprolagus hispidus*** **Pearson 1838. Leporidae** Hispid Hare	Herbivorous; SCF & RRF
13. ***Suncus murinus*** **Linn. 1766. Soricidae** Asian House Shrew	Scavenger; SCF
14. ***Pteropus giganteus*** **Brünnich 1782. Pteropodidae** Indian Flying Fox	Fruits; SCF
15. ***Pipistrellus paterculus*** **Thomas 1915 (not *Pipistrellus coromandra* Gray 1838). Vespertilionidae** Mountain Pipistrelle	Fruits, insects; Everywhere
16. ***Manis crassicaudata*** **E. Geoffroy 1803. Manidae** Indian Pangolin	Ants, larvae, insects; SCF
17. ***Felis chaus*** **Schreber 1777. Felidae / Felinae** Jungle Cat	Carnivorous; SCF
18. ***Felis silvestris*** **Schreber. Felidae / Felinae** Wild Cat	Carnivorous; SCF
19. ***Prionailurus bengalensis*** **Kerr 1792. Felidae / Felinae** Leopard Cat	Carnivorous; SCF
20. ***Panthera pardus*** **Linn. 1758. Felidae / Pantherinae** Leopard	Carnivorous; Everywhere
21. ***Paradoxurus hermaphroditus*** **Pallas 1777. Viverridae** Palm Civet	Carnivorous / consumes fruits; RRF
22. ***Herpestes edwardsi*** **E. Geoffroy - Saint Hilaire 1818. Nandiniidae** Indian Gray Mongoose	Carnivorous; Everywhere
23. ***Canis aureus*** **Linn. 1758. Canidae** Golden Jackal	Carnivorous & fruits; Everywhere
24. ***Vulpes bengalensis*** **Shaw 1800. Canidae** Bengal Fox	Carnivorous; Everywhere
25. ***Melursus ursinus*** **Shaw 1791. Ursidae** Sloth Bear	Omnivorous; SCF
26. ***Elephas maximus*** **Linn. 1758 (sub sp. *indicus* Cuvier 1798). Elephantidae** Indian Elephant	Herbivorous; Everywhere
27. ***Rhinoceros unicornis*** **Linn. 1758. Rhinocerotidae** Indian Rhinoceros	Herbivorous; RRF & RFF;
28. ***Sus scrofa*** **Linn. 1758. Suidae** Wild Boar	Herbivorous/Scavenger; Everywhere
29. ***Axis axis*** **Erxleben 1777. Cervidae / Cervinae** Chital	Herbivorous; SCF & RRF
30. ***Axis porcinus*** **(sub sp. *porcinus*) *Zimm.*1780. Cervidae / Cervinae** Hog Deer	Herbivorous; SCF
31. ***Muntiacus muntjak*** **(*muntjak-Ssp.*) Zimm. 1780. Cervidae / Cervinae** Red Muntjak/Barking Deer	Herbivorous; SCF
32. ***Rusa unicolor*** **Kerr 1792. Cervidae / Cervinae** Sambar	Herbivorous; RRF & RFF
33. ***Bos gaurus*** **H. Smith 1827. Bovidae / Bovinae** Gaur	Herbivorous; Everywhere

Table 4: - Abbreviations: 1 - Gorumara National Park; 2 - Ecotones (RFF, RRF & SCF) – vide section 2.1.1.; *Plant Parts

3.4 Salt Content of River Water and Average Rainfall

Salt content of river water showed remarkable seasonal variations, with a minimum during winter, at the range of 100 - 200 ppm TDS (EC 167 - 334 µS/cm^2) and maximum during rains, in the range of 300 - 450 ppm TDS (EC 500 - 750 µS/cm^2). The TDS levels remained moderate during pre-monsoon and pre-winter seasons (**Figure 3.**). The pattern of average monthly rainfall (excepting 1999 with 900 cm rainfall), were in the ranges of 0-20 cm in winter (Dec. - Feb.), 25-50 cm in summer (Mar. - May), 35-660 cm during rains (June - Sep.) and in the range of 15-90 cm in autumn (Oct. - Nov., **Figure 3.**).

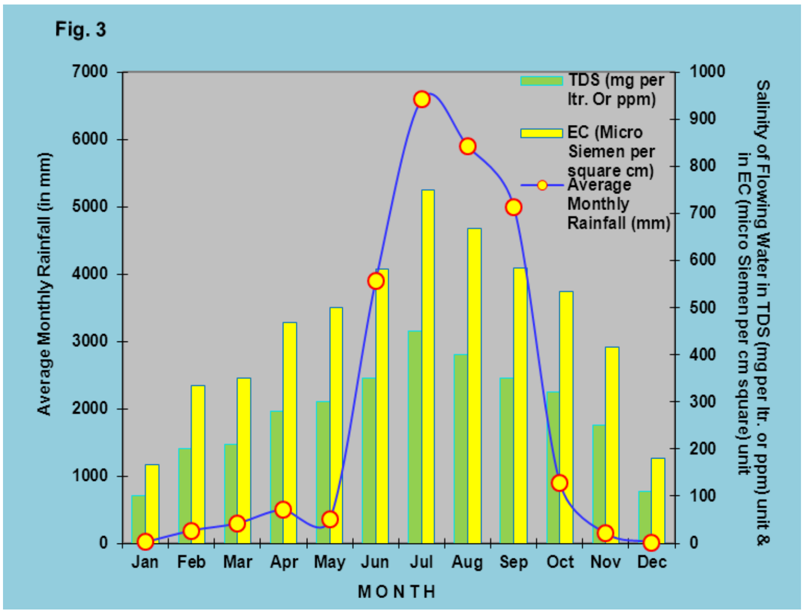

Figure 3. Average Monthly Rainfall and Salinity of River Water in GNP.

3.5 Geographical Location and Climate

The GNP is in the Duars (or Dooars; derived from 'Doors of Bhutan'; Duar in Hindi means door) of Malbazar Division, Jalpaiguri district, W. Bengal, India, with the Coordinates at 26 º 40′ - 26 º46′ N and 88 º08′ - 89 º02′ E and is delimited by an area of 90 sq. km. It is in the Eastern Himalayan Submontane Terai belt and ecologically falls in the Indo - Malaya Ecozone (Balakrishnan 1996; Murthy, Venu & Sanjappa 1996; Bhattacharya 1997; Singh 2000 a; Singh, Vohra & Singh 2000 b; Chettri et al 2010). The dominating seasons, with their average minimum - maximum ranges of temperature (℃) and percent relative humidity (% RH), are winter (Dec. - Feb.) with 5 ℃ - 21 ℃ & 65 - 80 % RH, summer (Mar. - May) with 16 ℃ –35 ℃ & 75 - 90 % RH, rainy season (June - Sep.) with 22 ℃ - 37 ℃ & 75 - 98 % RH and autumn (Oct. - Nov.) with 16 ℃ - 26 ℃ & 70 - 85 % RH (**Figure 4.**). The ever flowing Jaldhaka and Murti rivers, with web of rivulets changing their courses due to regular occurrence of monsoon flood, have produced distinct ecotones (Section 2.1.1. Plates 1 - 4). The vegetation is composed of Terai-Duars Savannah Grass Land, Tropical and Sub-tropical Grass Land and Shrub land, and with Moist Deciduous and Semi-Evergreen Tropical Sal Savannahs (Champion and Seth, 1968; Ghosh, 1994; Chauhan, 1996; Hazra, 1996; Roy, 1996; Srivastava, 1996).

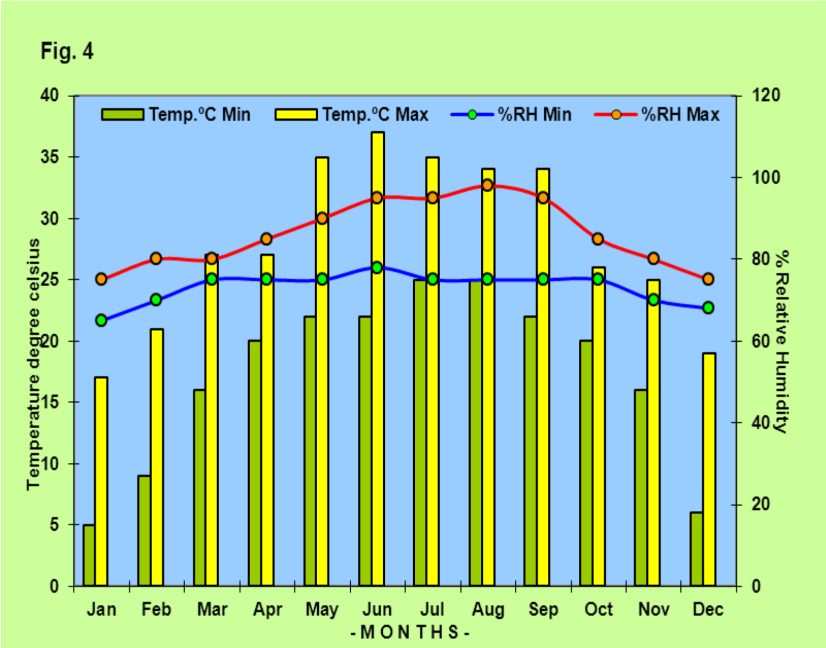

Figure 4. Range of Temperatures (^{0}C) and Relative Humidity (% RH) in GNP.

3. 6 Grazing Pattern & Food Habit of Wild Herbivores

Elephants and rhinos exhibited seasonal variations in their grazing pattern. During winter - summer seasons, when the salt content of flowing water sources is low (100 - 200 ppm TDS / EC 167 - 334 μS /cm^2; vide Section 3.4.), these pachyderms have been found to consume the whole of grasses, herbs and under-shrubs. The elephants tended to consume the inner fleshy parts of bark (rich in phloem tissues) of trees. The 'salt - licks' remained frequented by these herbivores. During rains, when salt content of the same was very high (320-450 ppm TDS / EC 500 - 750 μS/cm^2), pachyderms preferred the tender foliage and avoided 'salt licks'. However, the grazing pattern of gaur and smaller herbivores (Table-4) remained unchanged throughout the year.

4. Discussion

The findings (Sections 3.1.1. – 3.6) of experiments and observations have conclusively pointed out certain factors which are crucial for sustenance of the biodiversity of Gorumara National Park (GNP). These facts and factors have been enumerated in the followings to compose a guideline for better management of other tropical biodiversities.

4.1 Effect of Location on GNP

GNP Biosphere, in this typical Submontane Tropical Ecozone, is replete in suitable ecological factors (**Figures 3. & 4.**) which have enriched the area with very rich Biome comprising diverse types of vegetation (Sections 3.4., 3.5). Regular occurrence of monsoon flood, wipes out older vegetation that is already dwindling due to dry and hot tropical summer, rejuvenates the area with new soil, re-create salt deposits and initiates an ecesis with new grass land formation. This change in ecesis influences ecesis in other ecotones and enrich floral heterogeneity. Varieties of ecotones add to the floral and faunal diversity. The RFF and RRF ecotones give a buffering effect to the SCF heartland (Plates 1 – 4).


Plate 1. RFF Ecotone in Second Phase of Ecesis (Tondu Block)


Plate 2. Rhino home-land in RFF-RRF Ecotones (Dhupjhora Block)


Plate 3. Climax Riparian (RRF) Savannah (Budhuram Beat)

4.2 Implications of Species Diversity and Equitability Indices

High Floral and mammalian species diversity and equitability indices (Sections 3.1.2. & 3.1.4.) clearly indicate extreme species richness, evenness and complexity of flora and mammalian fauna. Floral species richness ensures food security of wild herbivores, while presence of large number of herbivores ensures removal of older plants by continuous grazing, removal of species dominance in the flora, enrichment of soil by faecal excreta. The presence of considerable number of carnivorous species (Table-3) keeps a population check on herbivores. Moderate floral diversities of RRF and SCF indicate stability of the niches, while low floral diversity (**Figures 1. & 2.**) in RFF is due to loss of species because of flood. Nevertheless, high diversity index reflects uncertainty of predicting the arrival of a new species. Although GNP is totally surrounded by highways, villages (Fig. 11) and tea gardens (Fig. 12), straying of wild animals into these areas is extremely rare, owing to the presence of rich floral heterogeneity and salt licks in GNP.

4.3 Salt Content of Flowing Water Courses Determines Feeding Patterns of Pachyderms

Consumption of the whole of small plants, barks, visiting 'salt-licks' during low salt level (100 ppm TDS or EC 167 $\mu S/cm^2$) and feeding on tender foliage during high salt concentration (450 ppm TDS / EC 750 $\mu S/cm^2$) of water courses (Section 3.6.), point-out that pachyderms require proper amount of salt to maintain salt-balance which in turn control their metabolism and migratory behaviour. Distortion in salt supplementation shall force the pachyderms to migrate and may become a source of conflict with forest bound populace.

4.4 Variability in Mammalian Food Habit

The varieties of feeds (Tables 1-4; Sections 3.2., 3.6.), which fill the palate of the mammals of GNP, demonstrate some sort of 'Adaptive Convergence' of the members of the mammalian fauna which might have crossed various ecological barriers of evolutionary significance.

4.5 Sapling Supplements

The creeping underground stem and rhizomes of grasses, which can survive drought, forest fire, flood, over grazing, and over grow other herbaceous species during ecesis, and the seeds retrieved from faecal matters (Section 3.2.) should be used for sapling production. These propagules play the most vital role in maintenance of floral heterogeneity.

4.6 GNP – a Model

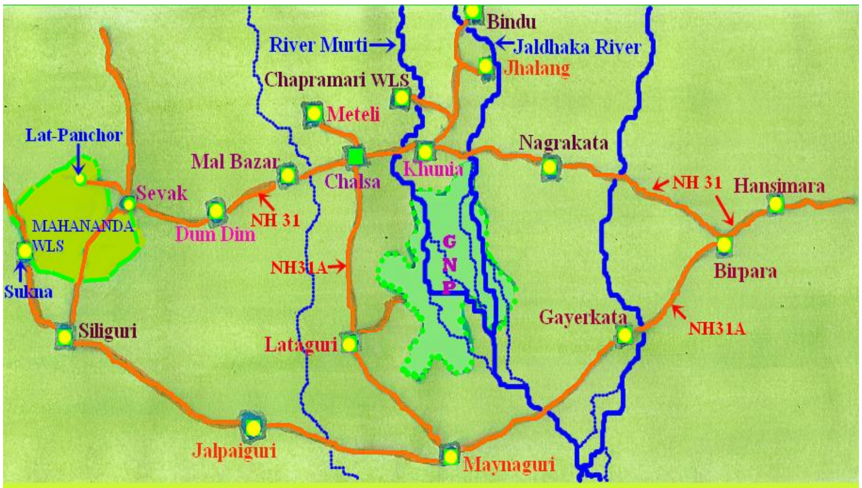

Plate 5. Road guide (not to the scale) to GNP & other WLS of Duars

It is amazing to note that in spite of being surrounded by well-populated human inhabitations (Plate – 5: - yellow dotted areas), there are rare incidences of wild mammals straying into these areas, which is attributable to the presence of conscious people in the surroundings and devoted forest personnel. Interactive biosphere with an enriched biome, fodder species richness, suitably supplemented water and minerals, efficient support staff and economic growth of forest bound populace from agriculture and eco-tourism enable GNP to be a model for management of tropical biodiversities.

Acknowledgement

Author expresses his gratitude and indebtedness to Mr. Manoj K. Nandi (the then PCCF-Wildlife) and Mr. Ujjal Bhattacharya, Mr. R. Dutta and Mr. Dipak Ranjan Raha (Mahananda W.L.S.) of Department of Forest, Govt. of West Bengal, India, for their help and cooperation during the early stages of this programme. In the later phase the cooperation provided by Mr. Bimal Debnath, R.O., GNP South Range, Wildlife Division II, Jalpaiguri, Department of Forests, Govt. of West Bengal, India, is acknowledged with great admiration. Author expresses his heartfelt thanks to Sri Tarapada Sil, laboratory assistant and to Mr. Pallab Jodder, student (Now is a manager of a tea estate in Dooars), for their uninterrupted help to collect samples. Author is also thankful to all his colleagues for extending their encouragement.

References

Andrea, C. A., & Russell, G. (2005). Are Epiphytes Important for Birds in Coffee Plantations? An Experimental Assessment. *Journal of Applied Ecology*, *42*, 150-159. http://dx.doi.org/10.1111/j.1365-2664.2004.00983.x

Arnold, A.E., & Engelbrecht, B.M.J. (2007). Fungal endophytes nearly double leaf conductance in seedlings of a Neotropical tree species. *Journal of Tropical Ecology*, *23*, 369-372. http://dx.doi.org/10.1017/S0266467407004038

Balakrishnan, N.P. (1996). Phytogeographic Divisions: General Considerations. In Hajra, P.K., Sharma, B.D., Sanjappa, M., & Sastry, A.R.K. (Eds.), Flora of India, Introductory Volume - Part I (pp197-204), Botanical Survey of India (BSI), Ministry of Environment (MOE), Government of India.

Begon, M., Harper, J.L & Townsend, C.R. (1996). Ecology: Individuals, Populations, and Communities. (3rd Ed.). Blackwell Science Ltd., Cambridge, MA.

Bhattacharya, U.C. (1997). *Introduction*. In Hajra, P.K. (Eds.), Flora of West Bengal, (Vol. - I, pp 1-66, 134-342), BSI, MOE, Govt. of India.

Bor, N.L. (1973). Grasses of Burma, Ceylon, India & Pakistan (Reprint ed.). Koenigstein-Ts, W. Germany

Chakraborty, K. (1991). Man Plant and Animal Interaction. Darbari Prokashan, Kolkata, West Bengal, India.

Champion, H.G., & Seth, S.K., (1968). A Revised Survey of the Forest Types of India. Manager of Publications, Delhi, India.

Chauhan, A.S. (1996). North-Eastern India and North Bengal. In Hajra, P.K., Sharma, B.D., Sanjappa, M. & Sastry, A.R.K. (Eds.), Flora of India, Introductory Volume - Part I (pp251-294), BSI, MOE, Govt. of India.

Chowdhery, H.J., & Hajra, P.K. (2000). Protected Area Network (PAN) : *In situ* Conservation Strategies. In Singh, N.P., Singh, D.K., Hajra, P.K., Sharma, B.D. (Eds.), Flora of India, Introductory Volume - Part II (pp 389-432), BSI, MOE, Govt. of India.

Cronquist, A. (1981). An integrated system of classification of flowering plants, Columbia University Press, New York.

Das, T. (Ed.), (2009). Birds of Gorumara National Park, DFO, Wildlife Division II, Jalpaiguri, Department of Forests, Govt. of West Bengal, India.

Dirzo, R., & Miranda, A. (1991). Altered patterns of herbivory and diversity in the forest understory: A case study of the possible defaunation, in Price, P.W., Liwinsohn, T.M., Fernandes, G.W., Benson W.W. (Eds.), Plant-animal Interactions: Evolutionary Ecology in Tropical and Temperate Regions, Wiley, NY.

Gaylard, A., Kerley, G. I. H. (1997). Diet of Tree Hyraxes *Dendrohyrax arboreus* (Hyracoidea: Procaviidae) in the Eastern Cape, South Africa. *Journal of Mammalogy 78* (1), 213-221. http://dx.doi.org/10.2307/1382654

Ghosh, S.B. (1994). Fodder Grasses of Indian Sanctuaries I - Identification of Grasses, Consumed by Herbivores, in the Mahananda and other Wildlife Sanctuaries of North Bengal. *The Indian Forester*,*120* (10), 946-952.

Hajra, P.K., Nair, V.J., & Daniel, P. (Eds.). (1997). Flora of India, Vol. 4, BSI, MOE, Govt. of India.

Israel, S., Sinclair, T., & Grewal, B. (Eds.). (1989). Indian Wild Life, APA Publication (HK.) Ltd. Hong Kong.

Jones, E.R., Curran, L.M., Wright, D.D., & Mack, A.L. (2008). Differential effects of mammalian seed predators on the regeneration of five Papua New Guinean tree species and implications for sapling recruitment. *Journal of Tropical Ecology*, *24*, 259-267. http://dx.doi.org/10.1017/S026646740800494X

Karthikeyan, S., Jain, S.K., Nayar, M.P., & Sanjappa, M. (1989). Florae Indicae Enumeratio, - Monocotyledonae, Flora of India, Series - 4, BSI, MOE, Govt. of India.

Leigh Jr., E.G., Wright S.J., Herre E.A., & Putz F.E. (1993). The decline of tree diversity on newly isolated tropical islands: A test of a null hypothesis and some implications. *Evolutionary Ecology*, *7*, 76-102. http://dx.doi.org/10.1007/BF01237735

Madhusudan, M.D. (2004). Recovery of wild large herbivores following livestock decline in a tropical Indian wild life reserve. *Journal of Applied Ecology*, *41* (5), 858 - 869. http://dx.doi.org/10.1111/j.0021-8901.2004.00950.x

Magurran, A. E. (1988). Ecological Diversity and its Measurement. Princeton University Press, Princeton, NJ.

Murthy, G.V.S., Venu, P., & Sanjappa, M. (1996). Physiography/Climate. In Hajra, P.K.,

National Atlas of India (1975). (1) Forest Types - Eastern India, Plate 105; (2) Wildlife and Wet land - Eastern India, Plate 99, Department of Science and Technology, Govt. of India.

of India.

Prain, D. (1903). Bengal Plants, BSI, Calcutta, Govt. of India, Reprint Published by Bishen Singh Mahendra Pal Singh, 1981, Dehra Dun, India.

Rosenzweig, M. L. (1995). Species Diversity in Space and Time. Cambridge University Press, New York, NY. http://dx.doi.org/10.1017/CBO9780511623387

Roth, D. S., Perfecto, I., & Rathcke, B. (1994). The effects of management systems on ground-foraging ant diversity in Costa Rica. *Ecological Applications 4*(3), 423-436. http://dx.doi.org/10.2307/1941947

Roy, G.P. (1984). Grasses of Madhya Pradesh, Flora of India, Series - 4, BSI, MOE, Govt.

Roy, G.P. (1996). Indo-Gangetic Plains, in Hajra, P.K., Sharma, B.D., Sanjappa, M. & Sastry, A.R.K. (Eds.), Flora of India, Introductory Volume - Part I (pp 220-224), BSI, MOE, Govt. of India.

Salim Ali & Ripley, S.D. (1987). Birds of India and Pakistan - together with those of Bangladesh, Nepal, Bhutan and Sri Lanka, Oxford University Press, Oxford - New York.

Sharma, B.D., & Sanjappa, M. (Eds.). (1993c). Flora of India, Vol. 3, BSI, MOE, Govt. of India.

Sharma, B.D., & Balakrishnan, N.P. (Eds.). (1993a). Flora of India, Vol. 2, BSI, MOE, Govt. of India.

Sharma, B.D., Balakrishnan, N.P., Rao, R.R., & Hazra, P.K. (Eds.). (1993b). Flora of India,

Sharma, B.D., Sanjappa, M., & Sastry, A.R.K. (Eds.), Flora of India, Introductory Volume - Part I (pp 1-15, 41-52), BSI, MOE, Govt. of India.

Singh, N.P. (2000a). Wasteland Development and Social Forestry. In Singh, N.P., Singh, D.K., Hajra, P.K., Sharma, B.D. (Eds.), Flora of India, Introductory Volume - Part II (pp 363-388), BSI, MOE, Govt. of India.

Singh, N.P., Vohra, J.N., & Singh, D.K. (Eds.). (2000b). Flora of India, Vol. 5, BSI, MOE, Govt. of India.

Sir Huxley, J. (Ed.). (1974). The Atlas of World Wild Life, Mitchell Beazley Publishers Ltd., London.

Srivastava, R.C. (1996). Eastern Himalayas – Sikkim. In Hajra, P.K., Sharma, B.D., Sanjappa, M., Sastry, A.R.K. (Eds.), Flora of India, Introductory Volume - Part I (pp 225-237), BSI, MOE, Govt. of India.

Stork, N.E. (1991). The composition of the arthropod fauna of Bornean lowland rain forest trees. *Journal of Tropical Ecology*, *7* (2), 160-180. http://dx.doi.org/10.1017/S0266467400005319

Storr, G.M. (1961). Microscopic analysis of faeces: A technique for ascertaining the diet of herbivorous mammals. *Australian Journal of Biological Science*, *14* (1), 157-164.

Svrček, M. (1988). Mushrooms and Fungi. Octopus Books, Artia, Prague.

The Environment (Protection) Act, Govt. of India –1986. Universal Law Publishing CO. PVT.LTD. (2010), Delhi, India.

The Forest (Conservation) Act/Rules, 1980/2003, Govt. of India. In The Indian Forest Act, 1927, Universal Law Publishing CO. PVT.LTD. (2010), Delhi, India.

The Wild Life (Protection) Act, Govt. of India, 1972. Universal Law Publishing CO. PVT.LTD. (2010), Delhi, India.

Verma, D.M., Balakrishnan, N.P. & Dixit, R.D. (Eds.). (1993). Flora of Madhyapradesh,

Vol. - I, Flora of India, Series - 2, BSI, MOE, Govt. of India.

Vol. 1, BSI, MOE, Govt. of India.

Weast, R.C. (1978). CRC Handbook of Chemistry and Physics, 59th ed., CRC Press, West Palm Beach, Florida, USA.

Wilson, D. E., & Reeder, D.A.M. (Eds.). (2005). Mammal Species of the World. A Taxonomic and Geographic Reference, 3rd ed., Johns Hopkins University Press, USA.

Web References

Anderson, H., Cummings, D., & Cummings, H. (1994), Measuring Salinity of Water. http://home.vicnet.net.au/~millcar/images/Measuring%20water%20salinity.pdf

Cancun Summit 2010; COP 16; CMP 5;

http://www.unfccc.int/resource/docs/2010/cop16/eng/02.pdf

Durban Summit 2011; COP 17 http://www.unfccc.int/resource/docs/2010/cop17/

Chettri, N., Sharma, E., Shakya, B., Thapa, R., Bajracharya, B., Uddin, K., Oli, K.P., & Choudhury, D. (2010). *Biodiversity in the Eastern Himalayas: Status, trends and vulnerability to climate change*; Climate change impact and vulnerability in the Eastern Himalayas – Technical report 2. Kathmandu: ICIMOD http://www.indiaenvironmentportal.org.in/files/biodiversity_in_the_eastern_himalayas.pdf