SUMMARY AND CONCLUSION

6.1. Summary:

Wetlands as transitional areas between land and water are of concern all over the world in matters of resource evaluation and utilization, environmental protection, pollution control, eco-restoration, biodiversity conservation etc. As such they have been drawing considerable attention of agriculturists, natural and social scientists, urban planners, land managers, landscape designers and many others. Since the issues of wetlands and their macrophytes in Puruliya district, West Bengal remained unattended; the present work entitled “Study of wetlands in Puruliya district, West Bengal, with special emphasis on their macrophytes” was taken up in 2007.

Puruliya, one of the hottest districts of West Bengal State lies between 23º 42’ North and 22º 43’ South latitudes and 86º 54’ East and 85º 49’ West longitudes. The district is under the regime of wet tropical monsoon type of climate. It covers an area of 6259.00 Sq Km where wetlands play a significant role in the life of the local people. In view of the biological, ecological and socio-economic importance of the wetlands the present work was undertaken to enumerate, locate and study them with special emphasis on macrophytes.

As many as 38 wetlands have been covered in this work whose individual area is greater than or equal to three acres. These wetlands occur in the 19 out of 20 Blocks of the District. From one Block, viz. Jhalda II no wetlands with an area of 3 acres or more could be identified. The data procured during field work in these locations were used in characterization of wetlands and their classification using different parameters such as location, ownership pattern, hydrological regime, size, biodiversity, threat perception, use and ongoing management practices, successional characteristics etc.

The wetlands, thus characterized, were classified on the basis of ownership. Majority of them (27) are privately owned, the rest being owned by the State Government(9) and only one(Barikbundh) is disputed and one (Dhanarbundh) vested.

Only five wetlands owe origin to rivers ( viz. Hanumata dam, Kalidaha Jore, Ketankiyari Jore, Kumari dam and Sindripathar)and the remaining wetlands are mostly rain fed. Wetlands like Benabundh, Benagora, Sindripathar are seasonal and the remaining 35 wetlands are perennials ensuring water availability throughout the year. Only five wetlands viz. Hanumata dam, Kalidaha Jore, Ketankiyari Jore, Kumari dam and Sindripathar are natural, all the rest being man-made. So far the use pattern of these wetlands is concerned as many as 31 wetlands have multifarious uses e.g. in pisciculture, irrigation and different domestic purposes. Only three wetlands, viz. Deshbundh, Dewanbundh and Kumaridam are exclusively used for irrigation and only four wetlands viz. Kamalabundh, Sahebbundh/Nibaransayar, Babirbundh/Sabirbundh and Barikbundh...
are used for domestic purposes, aesthetic effects, considered as sacred wetlands, and as source of drinking water respectively. In as many as 20 out of 38 wetlands, presently pisciculture is very poorly practiced so that the yield per annum hardly exceeds 25 quintals. 12 wetlands at present produce more than 25 quintals but less than 100 quintals annually. Each of three wetlands, viz. Adra Sahebbundh, Babirbundh, and Puranosayar have annual production ranging from 100 to 200 quintals and finally each of the three wetlands, viz. Hanumata dam, Joypur Ranibundh and Sahebbundh has an annual production within 200 to 400 quintals.

Domestic sewage is the main source of pollution in case of 19 wetlands. In 14 wetlands, agricultural runoff is the main source of pollution through which agrochemicals leach into the adjacent wetlands and urban sewage gets disposed to the remaining 5 wetlands viz. Barikbundh, Lihirbundh, Maidhara, Rajabundh and Sahebbundh/Nibaransayar. Wetlands in Puruliya are fortunate to have received neither any pollutant from industrial sources nor any biomedical wastes from hospitals, clinics and nursing homes.

Plant diversity is rich in 5 wetlands viz. Adra Sahebbundh, Burosayar, Joypur Ranibundh, Rampur Barabundh, Nibaran Sayar/Sahebbundh and moderately rich in 26 wetlands. In 7 wetlands, viz. Benabundh, Deshbundh, Gayerbundh, Ghoshalpukur, Kamalabundh, Khagerbundh, Ranibundh plant diversity is quite poor. Animal diversity is rich in 9 wetlands (Adra Sahebbundh, Babirbundh, Burosayar, Gayerbundh, Gobindasayar, Joypur Ranibundh, Mahatobundh, Rampur Barabundh, Sahebbundh/Nibaransayar) and moderately rich in 22 wetlands (Benabundh, Dewanbundh, Ghoshalpukur, Kamalabundh, Khagerbundh, Maidhara, Ranibundh) possess poor animal diversity.

The 38 wetlands of Puruliya district were further classified (clustered) based on their overall similarities applying the principle of numerical taxonomy or phenetics on their 34 two-state characters. As many as 38 initial single-point clusters each with a single wetland could be obtained at Zero(0) - linkage distance. All the singleton clusters were progressively grouped step by step with increase in linkage distance into larger (in content) but lesser number of clusters so that ultimately a single cluster is obtained for all wetlands at linkage distance of 4.6. Thus all the 38 wetlands have some sort of relationship in them and can be joined together in the cluster diagram. At the linkage distance of 4.0, three major clusters or MAJOR GROUPS (MG) were recognized; the first one (MG I) to include 14 initial single-point clusters, the second one (MG II) to include 18 initial single-point clusters, and the third cluster (MG III) with only 6 initial single-point clusters. Accordingly the number of wetlands in MG I, MG II, and MG III are 14, 18, and 6 respectively. Thus MG II is the largest among the major clusters. Each major group was further analyzed to reveal the degree of association of wetlands. The cluster diagram can be helpful in...
understanding the degree of overall-similarities (relationship) in the concerned wetlands and planning for each cluster a common strategy for restoration (optimization) and management for economic benefit and ecological welfare.

The physico-chemical characteristics of water and sediment samples were studied in case of three wetlands, viz, Adra Sahebbundh, Joypur Ranibundh and Nibaran Sayar or Sahebbundh(‘Bundh’ is a vernacular term applied to the wetlands by the local people). Water and soil samples (five in each case) were collected during the post-monsoon season of the years 2010 and 2011. The post-monsoon season was selected for this study since the wetlands overflow in monsoon and often many of them receive debris from the vicinity and in the dry pre-monsoon period dehydration leads to much contraction of water-bodies. The post-monsoon season especially the months of November and December, was thus considered ideal. Each of the ten parameters (pH, Electrical Conductivity, transparency, turbidity, total acidity, alkalinity, Dissolved Oxygen, Biological Oxygen Demand, Total Dissolved Solids, Total Hardness) studied showed certain variations in the concerned wetlands. The minimum values of pH(6.527),Transparency (33cm) were shown by Joypur Ranibundh and those of Turbidity(8cm),Acidity (15mg/l) were shown by Adra Sahebbundh. The minimum values of BOD (0.28mg/l),Total Hardness (3mg/l),TDS (108mg/l) were shown by Nibaran Sayar. The minimum values of DO (2.0mg/l) and Alkalinity (30mg/l) were shown by Adra Sahebbundh as well as Joypur Ranibundh and that of Electrical Conductivity (0.660 µmho/cm) was shown by Adra Sahebbundh and Nibaran Sayar.

Characteristically maximum values of pH (7.801), Turbidity (22cm), Alkalinity (51mg/l), DO (2.52mg/l)were shown by water samples from Nibaran Sayar and the same of Transparency(121cm), Acidity (45mg/l), Electrical Conductivity (1.02µmho/cm) were shown by the water sample collected from Joypur Ranibundh. The maximum value of Total Hardness(9 mg/l) and TDS(120.8mg/l) were shown by Adra Sahebbundh, and that of BOD (0.60mg/l) by both Adra Sahebbundh and Nibaran Sayar.

Soil reaction (pH) is one of the most important characteristics regulating not only life process but also availability of nutrients in water phase in optimum quality for the survival of organism. The mean pH values of sediments were found to be maximum in Nibaran sayar (6.03) and minimum in Joypur Ranibundh, (5.75). The pH values of the other wetland i.e. Adra Sahebbundh was found to be 5.85.

Soil conductivity indicates the free ions present in soil i.e. dissolved minerals which is essential for production. Values of Electrical conductance of sediment samples were found to be
maximum in case of Nibaran Sayar (2.95 \mu mho/cm) and minimum from both Adra Sahebbundh and Joypur Ranibund (2.11 \mu mho/cm).

The organic matter has predominant role in the process of biological production of wetlands. Maximum mean value of organic carbon was determined in Joypur Ranibundh (3.27 \%) and minimum in Adra Sahebbundh (2.19 \%). In case of Nibaran Sayar organic carbon was 2.77 \% of the sediment sample.

The values of total nitrogen was somewhat similar in case of the three wetlands, the values being 0.325\% of sediment in case of Joypur Ranibundh, 0.370\% in case of Nibaran sayar and 0.345\% in case of Adra Sahebbundh.

However, available-N was found to be highest in Nibaransayar (28.30 mg/100g) and lowest in Joypur Ranibundh (24.18 mg/100g). The value was 26.68 mg/100g in case of Adra Sahebbundh. Available-N in sediment is greatly influenced by the organic-C content in soil which is not reflected in many occasions in wetland ecosystem. This might be due to low nutritive values of organic matter with their slower rate of decomposition. At times, it is because of siltation over organic layer hindering its decomposition.

Available phosphorus was found to be highest in Joypur Ranibundh (19.08 mg/100g) followed successively by Adra Sahebbundh (13.72 mg/100g) and Nibaransayar (12.63 mg/100g). Potassium, the third major nutrient for aquatic production was found to be maximum in Adra Sahebbundh (17.76 mg/100g in each case) and minimum in Joypur Ranibundh (12.16 mg/100g). Sediment samples of Nibaran Sayar registered a value of 14.59 mg/100g

The highest mean values of pH, specific conductance, total-N, available-N of sediment samples could be recorded in case of Nibaran Sayar and those of organic carbon, C:N ratio and available phosphorous were scored in case of samples from Joypur Ranibundh. Adra Sahebbundh showed highest values of acidity, alkalinity, and available potassium concentration. The lowest values of organic-C, C:N ratio, and conductance were detected in case of Adra Sahebbundh and those of pH, total and available nitrogen, and available-K were minimum in case of Adra Sahebbundh. Values of available-P, acidity and alkalinity were lowest in case of samples from Nibaransayar. The unevenness especially in NPK and organic carbon contents of the three wetlands speaks of constrained metabolic activities linked with production.

The taxonomic account deals with 118 species of macrophytes associated with 38 wetlands of Puruliya district. The work presents keys to the identification of three concerned division of macrophytes, viz. Angiosperms, Pteridophytes and Algae. Keys to the genera have also been prepared for families with more than one genus as also keys to the species in case of genera with more than one species to facilitate ready identification. This is followed by standard
taxonomic description of the concerned species. The systematic account has been presented following the style of a standard Flora.

Taxonomic analysis reveals that in the floristic composition of wetlands in Puruliya district, angiosperm have participation in form of 62 species of 40 genera belonging to 26 dicotyledonous families and 52 species of 36 genera representing 14 monocotyledonous families. There are three species of pteridophytes representing the same number genera as well as families. *Chara fibrosa* is the only species of macroscopic alga which could be documented. The ratio of dicots to monocots in terms of species is 1:0.8; in respect of genera 1:0.9, and in context of families 1.85:100, thus indicating the major share of Dicots in the floristic scenario of wetlands in Puruliya. The concerned macrophytes are enumerated in the following.

**LIST OF PLANT NAMES**

**DICOTS**

1. *Nymphaeaceae* Salisb.

2. *Nelumbonaceae* Dunn.
   1. *Nelumbo nucifera* Gaertn.

3. *Fabaceae* Lindley
   1. *Aeschynomene indica* L.
   2. *Alysicarpus monilifer* (L.) Dc.
   3. *Crotalaria incana* L.

   2. *Drosera indica* L.

5. *Lythraceae* Jaume St. Hill.
   1. *Ammannia baccifera* L.
   2. *Ammannia multiflora* Roxb.
   3. *Ammannia senegalensis* Lam.

   1. *Ludwigia adscendens* (L.) H. Hara
   2. *Ludwigia perennis* L.

   1. *Trapa natans* L. var *bispinosa* (Roxb.) Makino.

8. *Turneraceae* Kunth ex C.D.
   1. *Turnera ulmifolia* L.

   1. *Centella asiatica* (L.) Urb.

    1. *Oldenlandia brachypoda* Dc.
    2. *Oldenlandia corymbosa* L.

    1. *Eclipta prostrata* (L.) L.
    2. *Enydra fluctuans* Lour.
    4. *Parthenium hysterophorus* L.
    5. *Spilanthes acmella* L.


13. *Boraginaceae* Juss
    1. *Heliotropium indicum* L.
    2. *Heliotropium strigosum* Willd.
   1. Nymphoides hydrophylla (Lour.) Kuntze.

15. Convolvulaceae Juss.
   1. Evolvulus nummularius (L.) L.
   2. Ipomoea aquatica Forssk.
   3. Ipomoea fistulosa Mart. ex Choisy

   1. Solanum nigrum L.

17. Scrophulariaceae juss.
   1. Bacopa monnieri (L.) Pennell
   2. Limnophila erecta Benth.
   3. Limnophila heterophylla (Roxb.) Benth.
   4. Limnophila indica (L.) Druce
   5. Limnophila repens (Benth.) Benth.
   6. Limnophila rugosa (Roth) Merr.
   7. Limnophila sessilisflora (Vahl.) Bl
   8. Lindernia crustacea (L.) F. Muell
   9. Lindernia parviflora (Roxb.) Haines
   10. Verbascum chinense (L.) Sant.

   1. Utricularia aurea Lour.
   2. Utricularia australis P. Taylor
   3. Utricularia bifida L.
   4. Utricularia stellaris L. f.

19. Acanthaceae Juss.
   1. Hygrophila difformis (L. f.) Sreem & Bennet
   3. Hygrophila schulli (Schumach) Heine

20. Verbenaceae J. St. Hill.
   1. Phyla nodiflora (L.) Greene

   1. Boerhavia diffusa L.

22. Amaranthaceae Juss.
   1. Alternanthera philoxeroides (Mart.) Griseb.
   2. Alternanthera sessilis (L.) Dc.
   3. Gomphrena seratta L.

23. Polygonaceae Juss.
   1. Polygonum hydropiper L.
   2. Polygonum orientale L.
   3. Polygonum pulchrum Bl.

   1. Peperomia pellucida (L.) Kunth.

   1. Croton bonplandianum Baill.

26. Ceratophyllaceae S. F. Gray
   1. Ceratophyllum demersum L.
   2. Ceratophyllum muricatum Cham

MONOCOTS

27. Hydrocharitaceae Juss.
   1. Blyxa japonica (Miquel) Maxim. ex Ascherson et Gurke
   2. Hydrilla verticillata (L. f.) Royle
   3. Nechamandra alternifolia (Roxb. Ex wight) Thwaites
   5. Vallisneria spiralis L.

   1. Eichhornia crassipes (Mart.) Solms
   2. Monochoria hastata (L.) Solms
   3. Monochoria vaginalis (Burm. f.) C. Presl

29. Commelinaceae R. Br.
   1. Commelina benghalensis L.
2. Commelina paludosa Bl.
3. Murdannia nudiflora (L. ) Brenan
4. Murdannia spirata (L. ) Bruckner

1. Juncus prismatocarpus R. Br.

31. Typhaceae  Juss.
1. Typha domingensis Pers.

32. Araceae  Juss.
1. Colocasia esculenta (L. ) Schott.

33. Lemnaceae  S. F. Gray
1. Spirodela intermedia W. Koch

34. Alismataceae  Vent.
1. Sagittaria guyanensis Humbolt.
2. Sagittaria sagittifolia L.

35. Aponogetonaceae  Hill.
1. Aponogeton appendiculatus H. Br. gen
2. Aponogeton natans (L. ) Engler et Krause
3. Aponogeton undulatus Roxb.

36. Potamogetonaceae  Dum.
1. Potamogeton crispus L.
2. Potamogeton nodosus Poiret

37. Najadaceae  juss.
1. Najas graminea Del.
2. Najas malesiana de Wilde
3. Najas minor All.

38. Eriocaulaceae  Desv.
1. Eriocaulon quinquangulare L.

1. Cyperus difformis L.
2. Cyperus haspan L.
3. Cyperus iria L.
4. Cyperus platystylis R. Br.
5. Eleocharis atrorupurea (Retz.) Presl.
7. Fimbrystilis milacea (L.) Vahl.
8. Fimbrystilis polytrichoides (Retz.) Vahl.
11. Schoenoplectus articulatus (L.) Palla
12. Schoenoplectus grossus (L. f.) Palla

40. Poaceae  Bar. hart.
1. Brachiaria eruciformis (J. E. Smith)

Griseb.
4. Hygrorhiza aristata (Retz. ) Nash
5. Leersia hexandra Sw.
7. Oryza sativa L.
8. Panicum paludosum Roxb.
9. Panicum repens L.
10. Paspalum conjugatum Bergius
12. Vetiveria zizanioides (L. ) Nees ex
Wright et Arnott.

41. Marsileaceae  Mirab.
1. Marsilea minuta L.

42. Isoetaceae  J. Roux.
1. Isoetes coromandeliana L. f.

43. Saviniaceae  Polhillm.
1. Salvinia natans (L. ) All.

44. Characeae  R. D. Wood
1. Chara fibrosa Ag. ex Buz.
Summary and conclusion

From the taxonomic account analyses were made of different aspects having relevance to the understanding of the biology of macrophytes. Since sustenance of wetlands depends on the sustenance of macrophytes thorough knowledge of their growth-forms, life-forms, ecophases, status and propagation is essential. In view of this the discussion part concerning taxonomic studies has dealt with all these aspects along with determination of dominant families and genera, analysis of wetlands vis-à-vis number of species, macrophyte prevalence, forms in relation to water, flowering and fruiting periods and propagation. The facts thus revealed may find practical application in species conservation.

Growth-form categories of dicots show dominance of ‘herbids’ in the wetlands of Puruliya district. Besides this, there are nine other growth-forms, viz. Utricularids, Ipomeids, Trapids, Aeschynomenids, Decodontids, Nymphaeids, Vittate, Nelumbids, Myriophyllids each of which has specialization of its own kind.

The concerned macrophytes were found to belong to 7 life-form categories. The Pelochthophytes dominate over other life-form categories being successively followed by Octohydrophytes, Pleustophytes, Euhydratophytes, Acrohydratophytes, Tenagophytes and Hydrochthophytes.

The concerned macrophytes could be put under four distinct ecophase categories of which terrestrial ecophase is dominating being successively followed by Hydrophase, Littoral and Limosal ecophases.

Utilitarian aspects of macrophytes

In case of wetlands in Puruliya district are concerned, the concern of people in the vicinity is mainly for water since the district is very hot and dry in the major part of the year. The water is used for domestic purposes, irrigation and agricultural activities. Their interest in macrophytes is rather to a lesser extent. The present work could document the use of only 31 species from the users of wetlands. As many as 11 species were found to have medicinal uses against diseases of different types. Leaves of 10 species were found getting cooked as green vegetable. Stem pedicels and flowers of *Nymphaea pubescens*, seeds of *Nelumbo nucifera* and *Nymphaea pubescens* are cooked and eaten. Fruits of *Trapa natans* are eaten raw whereas fruits of *Solanum nigrum* are cooked as vegetable. Leaves of three species of *Najas* and *Vallisneria spiralis* are useful as poultry feed. Medicinal use of rice leaves seems to be novel. *Oryza sativa* and four other species are used in worships and festivals. This kind of use has conservational implications. So perpetuation of the religious activities can ensure conservation of these useful species. Two species have been recorded to have use in fencing and as fuels. Prophylactic use of two species
against leprosy is noteworthy. Use of *Bacopa monnieri* in conjunctivitis is a novel information. Use of three species in gynecological disorders is also noteworthy. That the fruits of one wetland associated species is used to trap rats and leaves of another species is used as plates have also been observed and recorded. Of the various types of uses, those of medicinal plants and edible wild plants seem to be the most important. The edible wild plants have prospect in addressing the issues of food security in future. From the information documented regarding use of macrophytes it seems that these plants are intimately associated with the poor people of the wetland locality. Programmes of conservation and management should be undertaken in the near future for optimum sustainable utilization of the wetland bioresources for economic benevolence of the local people.

As such the present work proposes remedial measures in form of a model. The specific suggestions mentioned in the model include use of hyper-accumulating macrophytes for pollution mitigation, regulation of irrigation, desiltation, conservation of fringe-area soils by growing soil binding species, and wind checking trees, raising of gardens around wetlands, banning of washing of automobiles, input of urban sewage and dumping of other obnoxious wastes, prohibition of unhygienic domestic use and unethical defecation, removal of excess nutrient load by judicious removal of biomasses etc. Keeping in mind that for conservation of wetland resources, restoration projects must be implemented collaterally with sustainable utilization of the resources. As such, another model has been prepared to suggest wetland wise sustainable developmental programmes through launching of Integrated scientific programmes for pisciculture and duckery for 24 wetlands, floriculture (*Nelumbo nucifera, Nymphaea pubescens, Nymphaea nouchali* etc.) at least for 9 wetlands, establishment of Cottage industry (mats/sola, art and craft etc) for 6 wetlands, establishment of Co-operatives and Societies for employment generation through scientific pisciculture and other activities at least in case of 5 wetlands, promotion of tourism for 5 wetlands, initiation of vermicomposting of organic matter removed from wetlands during management practices in case of 17 wetlands, establishment of biogas plant and dry anaerobic composting with the organic matter removed during management in case of two wetlands.

6.2. Conclusion:

i) From the sum and substance of the present work it is conceivable that most of the wetlands in Puruliya District are associated with rural as well as urban lives, their values being mostly linked with the amelioration of chronic problems arising from water scarcity. In a drought prone district like that of Puruliya wetlands deserve a very high status of significance. The general awareness of multifarious environmental implications, aesthetic values and economic potential of
wetlands is inadequate. This work can be used to promote awareness beyond the general consideration of wetlands merely as water-reservoirs.

ii) The wetland inventory and the map presented in this work are compliant with its objective of contributing towards the Wetland Directory of the state as well as of the country. The map can be used in general physical planning programmes and in finding out the sites for creation of new wetlands, delineation of conservation areas and ecological units. The inventory can also afford opportunities for co-operation in matters of information exchange regarding resource utilization.

iii) Major steps that need to be taken up in Puruliya District for sustaining wetlands for promotion of economic development and ecological welfare are enumerated in the following. Greater emphasis should be placed on promoting wetland awareness among local people, students of Schools, Colleges and Universities. Professionals and non-government bodies also need to be trained in this regard. Occupational, environmental and health issues of wetland neighbours and users need to be studied in an integrated way so as to optimize human health and ecosystem.

(iv) Cooperative societies need to be established with local people for sustainable and profitable use of wetlands. Optimum diversity of plants and animals should be maintained in a scientific manner for the sustainability of wetlands ecosystem.

(v) Rapid eutrophication needs to be controlled through judicious removal of plants maintaining the species diversity and optimum productivity.

(vi) Irrigation of agricultural fields with water from wetlands, especially in dry seasons, needs to be rationalized and regulated.

(vii) The regulatory Authorities (State Department of Environment/Central Pollution Control Board/State Pollution Control Board and others) should ensure through constant monitoring that adequate steps are taken by the Polluting agencies (industries and hospitals etc) for mitigation and control of pollution.

viii) The taxonomic account dealt with in this work is likely to be contributory to stock-taking of the wetland biodiversity as well as to the preparation of a District Flora. All these species in general and those pointed out as regionally threatened ones deem consideration for protection to sustain the form in rhythm with the functions of wetlands.