Indian Journal of Agricultural Economics 77: 3 (2022):521-529
DOI:10.63040/25827510.2022.03.010

Ecosystem Services of Riverine Wetlands with Special Reference to the Upper Brahmaputra Basin

S. P. Biswas and A. Santoshkumar Singh*

ABSTRACT

Floodplain wetlands in the Upper Brahmaputra basin (UBB), locally known as *beel* are biologically rich and highly productive ecosystems that support myriads of aquatic flora and fauna. Covering an area of about 0.1 million ha, the wetlands of the area are five major types (a) oxbow lakes, (b) tectonic lakes, (c) man-made tanks, (d) low-lying paddy fields, and (e) seasonal pools. In addition to flood-plain lakes, there are man-made tanks that have tremendous ecological and economic importance. High fishing pressure and climatic variability of the region have experienced a significant reduction in the wetland bio-resources. Deforestation in the catchments, construction of roads and embankments and blockage of feeder channels of floodplain lakes also contributed to the reduction of habitat complexity. Rapid urbanisation and industrialisation led to the crumbling of water quality and shrinking of biodiversity by abuse and contamination of freshwater resources. Further, improper disposal of solid waste and non-biodegradable materials and contamination of natural water bodies by agricultural pesticides, injudicious mining from river-bed have also complicated aquatic life. The present study reviews the status of the floodplain wetlands in the Upper Brahmaputra basin, their bio-resources as well as economic and ecological services rendered by them. It also synthesises the updated knowledge and analyses the challenging issues of wetland management in the context of changing temperature and rainfall patterns.

Key words: Flood-plain lakes, fish fauna, ecosystem services, Upper Brahmaputra basin
JEL: Q22, Q23, Q25, Q57

I

INTRODUCTION

Floodplains are low-lying areas, bordering rivers, which are inundated during the rainy season primarily by overspill from the adjacent river and thereby reducing flood damage to riparian settlements. Species composition and species diversity vary widely in the riparian ecotone of the upper reaches of the Brahmaputra basin (UBB) and the basin is the abode of over 300 species of fish and other megafauna, (Biswas et al., 1997). Most of the fish species are either temporary or permanent 'residents' of the adjoining flood-plain lakes (*beels*) and these are the feeding and breeding ground of most of the riverine fish species in Assam (Biswas and Michael, 1992; Biswas, 1996; Boruah and Biswas, 2002). However, this hitherto unpolluted river system suffers a gradual decline in habitat quality due to changes in 'water regime' especially the seasonality and hydrograph of the river system as well as high rate of bank erosion (Biswas et al., 2000; Biswas and Boruah, 2000). This is more so in the wetland habitats as the destruction of beel habitats has been order of the day in

* Department of Life Sciences, Dibrugarh University, Assam-786 004 and Department of Zoology, Pravabati College, Mayang Imphal, Imphal West, Manipur: 795 132, respectively.

recent years (Abujam *et al*., 2014 a, b) and conservation of wetlands and their biota are, therefore, the need of the hour. The present paper focuses on certain environmental, ecological and legal issues of the wetlands in context with their bioresources and strategy for their sustainable utilisation.

General Features of Wetlands: Wetlands of the region (UBB) are broadly categorised as (a) Oxbow lakes (open *beel*); (b) Tectonic lakes (close *beel*); c) Seasonal water-logged areas; (d) Man-made tanks (wetlands). Over 5,000 large-sized wetlands and about 6,000 medium and small wetlands cover an area of 7,64,372 ha which accounts for about10 per cent of the total geographical area of Assam (Anon., 1997). Turbidity in beel water is primarily due to silt and organic matter carried by the run-off waters from the catchment areas and also from the connecting river in the case of open *beel*. During rainy months (May to October), the river water remains highly turbid and primary production in the river is also very low (Biswas and Baruah, 2000; Boruah and Biswas, 2002). Joysagar and Sivasagar tanks in Upper Assam are the most transparent water bodies irrespective of the season (Biswas, 1996). It is the adjacent floodplain lakes (beels), which not only provide food and shelter for most of the riverine species but also breeding grounds for them including the Indian Major Carps (IMCs) (Biswas and Michael, 1992). Further, beels hold excess flood water; these water bodies are the natural sink for waste materials and flood mitigation.

Species diversity is the key element of an ecosystem. Wetlands in the UBB have the residential and migratory forms of ichthyofauna (Choudhury and Biswas, 2004). Fish production is highly variable. On average minor carp, barbs and small catfishes together contribute about 60per cent of the landings. The air-breathing group shares about 30per cent of the catch during dry months. Giant catfishes and IMCs contribute about 10per cent of the catch between November and April. Apart from perennial wetlands, seasonal water bodies like paddy fields, roadside canals, ditches etc. also serve as natural habitats for many small, wild and ornamental fishes which breed in the water bodies (Das and Biswas, 2018). Ironically, most of these water bodies are underutilized. The availability of huge array of seasonal water bodies in Upper Assam provides ample opportunities for aquaculture development.

II

ECOSYSTEM SERVICES (FISHERIES) RENDERED BY OF SOME WETLANDS OF UBB

Maguri Beel: Maguri is situated 27°33′795″ to 27°34’357″ N and 95°22’081″ to E 95°22′190″E at an altitude of 96.1 msl in Tinsukia district and adjacent to the Dibru-Saikhowa National Park. It is an ‘open’ beel that is connected to the river Dibru and in fact, the river actually flows through the wetland. Maguri covers an area of 167.40 ha at Full Storage Level (FSL) and 117.18 ha at Dead Storage Level (DSL). The depth of Maguri ranged between 0.95 and 4.3 m. A marked fluctuation in the physicochemical parameters of the connecting channels has been noticed

between rainy and dry months. Water temperature varied from 15.2 to 30.70 C, pH from 6.35 to 8.27, D.O. from 4.4 to 8.7 mg/l and total alkalinity from 40 to 80mg/l indicating that the wetland is more or less is eutrophic in nature and moderate to highly productive. A prominent tourist destination in upper Assam and also a major source of fisheries especially endemic and rare ornamental fish species (Biswas *et al*., 2007) Maguri- Motapung wetland complex is a source of livelihood for thousands of inhabitants.

Moridikhow: Moridikhow is an ox-bow lake in the Sivasagar District. It is a productive wetland from a fisheries point of view. This weed-infested wetland is an abandoned channel of R. Dikhow. Water temperature was observed as 17.9°C (January) to 31.4°C (August); transparency from 0.83 (August) to 2.23m (April); alkalinity ranged from 46mg/l (July) to 106mg/l (December) and conductivity value decreased from 72µs/cm (monsoon) to 50.33µs/cm (winter). Source of potable water and fishery for a vast area.

Joysagar tank: Several huge man-made tanks such as Sivasagar, Joysagar, Rudrasagar, Borpukhuri (Nazira), Rajmao, etc. were excavated during the Ahom dynasty some 600 years ago. Covering an area of about 48,000m^2, it is one of the prominent tourist spots in Assam for its historical importance and scenic beauty. It has a rich fish and benthic-fauna (Sarma and Biswas, 2012) and is also an important habitat for migratory birds. The water level, like other such tanks, remains almost constant throughout the year. The tank is the main source of potable water in the surrounding area.

Gelabeel: Gelabeel, an ox-bow lake of Golaghat District is a productive water body and rich in fish fauna. During the rainy season, the environmental conditions promote the activation of the soil microbial processes which favoured the soil N availability. The normal range of pH in Gelabeel was found between 6.7 and 7.35. This is very much ideal for fish productivity. High DO content was observed in August (9.00mg/l) which might be due to the increased photosynthetic activity facilitated by increased temperature and pH. Low DO content during January to April might be due to the intensive fishing done by fishermen, as these months are generally festive months in Assam. Sixty three fish species were recorded from this wetland of which Cyprinidae showed the highest (21) number.

*Maijan beel***:** The Maijan beel in the Dibrugarh district of upper Assam is an oxbow lake having a direct connection with the Brahmaputra River and is located at $27^0$30’14.4” N latitudes and $94^0$58’04.8” E longitudes. It is located at an elevation of 86-102 m above MSL. The wetland is spread over an area of 44.50 ha and its maximum and the minimum depth is 9m to 3 m respectively. The water body is completely surrounded by tea gardens and water quality has somewhat changed due to the influx of untreated wastes water from adjacent tea gardens (Dakua *et al*., 2009). The beel is rich in fish diversity, but due to ecological degradation and other excessive human activities (Abujam *et al*., 2014 a,b). 54 fish species were recorded from Maijan (Abujam *et al*., 2009).

Borsola beel: Borsola beel (N 26º50′ 22.3″ and E 94º 13′ 12″) is one of the largest floodplain wetlands in Upper Assam with an area of 90 ha. Borsola beel is open type and it is about 15 km from Jorhat town. The depth of Borsola ranged from 8 to 15 m. Over the years the water quality of the wetland has changed due to the influx of waste water and excessive human activities (Bordoloi *et al*., 2012). The wetland is the main source of income for the fishermen, and they are directly and indirectly dependent on the fish catch from the *beel*.

*Potiasola beel***:** Potiasola is a closed-type wetland located in the Jorhat district (N 26^{0}50′ 10.1″ and E 94^{0}12′ 17.4″) with an area of 66 ha. The depth of Potiasola ranged from 0.8 to 8.0 m. Earlier, the beel was connected through a feeding channel known as Bejijan but the channel is now completely lost due to the embankment of the Brahmaputra River. During the winter the catchment area of the beel is utilized for the cultivation of vegetation and as well as it is also utilized for feeding the ground of buffalo and cattle (Bordoloi et al., 2012). The soil of the beels is of the alluvial type.

Ephemeral streams: Seasonal streams of the Lakhimpur district harbour several types of loaches and barbs. One of the streams, *Singijan* is contaminated by tea-garden pesticides. The FBI value of macro-invertebrates indicated a fairly poor quality of water indicating organic pollution in the studied areas. Biomonitoring Working Party Index (BMWP) also indicated slight pollution of seasonal streams due to human activities. During monsoon higher density and diversity of fish were recorded. Extraction of sand and gravel from stream-beds, and changing land use patterns are some major factors responsible for declining species diversity (Boruah *et al*., 2008; Biswas *et al*., 2018).

III

MAJOR ISSUES RELATED TO WETLAND FISHERIES:

Since the 1970s a gradual decline in fisheries in the entire Brahmaputra has been reported (Biswas, 1996). Various reasons have been attributed to low fish yield in the Brahmaputra basin. Siltation and geomorphological changes are the two natural factors that impacted fish production in the region over the decades. Besides, there are other problems related to riverine and beel fisheries in the region – (a) Shrinkage and alteration of fish habitats (Nayak and Biswas, 2020) due to construction of embankments and developmental (river dam) projects; (b) Urbanization and solid waste disposal in the wetlands; (c) Mining activities - unscientific exploitation of sand and stones/ boulders from the river bed resulted in habitat loss of many small fishes; (d) Fishing pressure/ unscrupulous fishing using small meshed nets; (e) Agricultural pollution.

Encroachment and over-exploitation of resources mainly fish from these wetlands coupled with the conversion of low-lying land for agricultural purposes have already threatened the wetland habitats. Indiscriminate killing of fish by using

pesticides and other illegal devices is another major threat to the already depleted fishery resources of the floodplain lakes (Choudhury and Biswas, 2005).

'*Flood pulse' and its impact on aquatic biota***:** It is observed that the *beels* receive back-flow water from the connecting river or from the huge catchment area following monsoon rains. A prolonged rainy season (April to October) especially in Arunachal Pradesh causes regular floods in Assam which helps, among other things, the auto stocking of *beels*. Auto stocking of the open *beel* is facilitated by the influx the flood water when many riverine species including the IMC enter the *beel* for spawning purposes. The annual flood not only rejuvenates the *beels* by recharging them with fresh water and nutrients but also flushes out the floating weeds which otherwise would have choked the *beels* and thus the flood water delays eutrophication.

*Aquatic pollution***:** Aquatic pollution and destruction of planktonic fauna and small fishes in the water bodies in and around tea gardens were reported (Biswas, 1996) and the situation is still no better. Extensive use of pesticides in tea and agriculture has an adverse impact on other aquatic biota also. These types of chemicals which are inadvertently mixed with seasonal water bodies as run-off are not only dangerous to the fish life but also to the whole food chain and ultimately to human habitat.

*River embankments and Dams***:** One of the reasons for declining the natural stock of Indian major carp in the Brahmaputra system is the construction of 'ecologically detrimental' river embankments. Similarly, damming of tributaries will invariably have a bearing on the 'environmental flow' which in turn has a severe impact on the assemblage of fish and other aquatic biota in the wetlands. Let there be embankments, but the connectivity of the channels of natural wetlands should be retained by providing sluice gates.

*Fishing pressure***:** Fishing is conducted throughout the year except during high flood and festival days. The maximum fishing, however, is done when the flood water recedes. The use of fine-meshed *kapda jal* (mosquito net) is highly destructive as fish eggs and spawn are also caught in it. Another highly destructive gill net, known as *current jal* is responsible for the mass killing of fish. In remote areas, explosives and pesticides are freely used to catch fish. *Jeng* fishing too is an unsustainable fishing method.

IV

SOCIO-ECONOMIC STATUS OF FISHERFOLK

It is estimated that 0.2 million people are directly or indirectly involved in fishing activities in the Brahmaputra basin. The socio-economic status of the *beel* community is very poor. The majority are under the BPL category with an annual income ranging from INR 20,000 - INR 50,000 per family. All the fishers who were directly involved in fishing as being the primary source of livelihood not long ago, but the majority of them are now involved in other activities for additional

income generation. This indicates that fishing alone is not providing them adequate earnings for the maintenance of their families at present.

Public view on the fish resource status: An interview with 139 fishermen of the three fishing villages in and around Maguri *beel* in upper Assam revealed that depletion in the number/quantity of fish over the last three decades. The depletion of fish stock in the *beel* may be attributed to natural and indiscriminate fishing, siltation along with other related factors like changes in the temperature and rainfall pattern. The respondents suggested that prevention of poisoning, small meshed net and adoption of the culture-based fishery can save the ichthyofauna of the wetland complex.

V

DISCUSSION

Floodplain lakes are among the most productive fishery resources and sources of livelihood for millions of rural people across the world. The shallow and eutrophic flood plain lake (FPL) of the Ganga-Brahmaputra-Meghna (GBM) basin in South Asia is highly rich in fishery resources and livelihood options for an estimated 10 million fisher-folks in the Indian sub-continent. Further, these FPL act as feeding and breeding ground for many riverine species (Biswas, 2014).

Among all the hydrological factors, 'flood pulse' is probably the strongest factor that regulates other limnological conditions and faunal distribution in the wetlands of the basin. Usually, there are three or four high floods between May and October and fish migration is intimately related to this flood regime. A huge amount of sediments unloaded by the Brahmaputra in the plains causes siltation of river beds, changes the river courses, braiding of the channels and increases the frequency of floods. During the dry season, fishing is mostly restricted to near the confluence of tributaries or channels and also at river meanders (Boruah and Biswas, 2002). However, changes in the rainfall and flood pattern experienced in recent decades have a great bearing on the faunal composition of the Brahmaputra river and its linked ecosystem (Biswas, 2014). Construction of roads and embankments and blockade of feeder channels of floodplain lakes also contributed to the reduction of habitat complexity. Habitat alteration often leads to shallow channels drying up during non-rainy months. Thus natural and anthropogenic interventions have drastically reduced the production potential of the natural water bodies (Boruah and Biswas, 2002). Anthropogenic perturbations and physical disturbances like illegal fishing, deliberate use of pesticides and also from run-offs from adjoining agricultural lands seriously affect the wetland fish resources (Biswas and Boruah, 2000, Biswas and Das, 2009).

Many ecologists now advocate the integration of regional and historical processes, as well as species interactions within local habitats (Ricklefs 1987, 2008; Cornell and Lawton, 1992; Rosenzweig 1995). This implies that local communities

are affected by factors that operate at large spatial and temporal scales to shape regional diversity (Cornell and Karlson 1997). Another paradoxical view is that "Nature destroys nature more than humans". If we base our present study on this, probably this could be validated well in the Maguri wetland complex. Annual flood in the Brahmaputra basin, avulsion and excessive erosion and aggradations (Biswas *et al.,* 2000; Boruah *et al*., 2008) resulted in various changes in the wetland system of the upper Brahmaputra basin and the cumulative impact on the bioresources and humans and the changing trend of dependency on the wetland. Natural changes have impacted much on the land use-land cover, habitat alterations-both faunal and livelihood patterns of the local residents (Boruah and Biswas, 2001).

VI

RESEARCH AND POLICY ISSUES:

The Upper Brahmaputra basin encompasses part of the eastern Himalayan region covering Assam, Arunachal Pradesh, and Nagaland – the trijunction of India, China and Myanmar. The wetlands scattered throughout the region are globally recognised for their biological wealth, thereby assuming a great significance in terms of ecological, economical and social benefits for the region. However, wetlands are in a poor state due to intense pressure from a wide range of anthropogenic disturbances:- altered land use and flow regimes, shrinkage of habitat, water pollution, exotic species invasions, and intensive exploitation of fish stocks. Most of the wetland management research in India focuses on limnological elements and ecological/environmental economics. However, little research has been carried out on the physical and socio-economic processes that result in limnological changes. The institutional features of wetland management have only recently attracted the interest of research. Key issues are institution related, infrastructure and production related, supply and delivery related and also societal which are outlined as follows :

Establishment of Wetland Regulatory Board: In the name of development and economic growth, most of the wetlands have been used for urban development or as dumping sites for municipality wastes. The establishment of Wetland Regulatory Board in line with the State Biodiversity Board is the need of the hour.

Sustainable Utilisation of Wetland Biota: Although we have no hard data, it is estimated that about 60per cent of the fish species available in the region are found in the wetlands of the basin. Residents in the vicinity of wetlands are also dependent on varieties of wetland resources. Unscrupulous exploitation of resources should be avoided in order to get long-term benefits.

Contingency Plan for Mitigation of Extreme Weather Impact: In the last few decades, with an increase in the frequency of extreme weather events such as high-intensity rainfall, high rate of siltation and often rising temperature resulting in a drought-like situation has had a great bearing on the wetland biota. In a highly precipitated zone like N.E. India, the creation of ponds/ artificial lakes in specified

areas will be helpful to mitigate urban flood, and also a potential area for recreation and aquaculture. A restoration plan for mitigating the impact of climate change has been advocated for biodiversity conservation and carbon storage.

Strict Compliance with Existing Environmental and Fisheries Acts: Problems such as unregulated fishing and overfishing, use of destructive methods of fishing, habitat destruction, etc. are putting increased pressure on the aqua resources to meet the ever-increasing market demand. EIA for any developmental project should be mandatory.

Promotion of culture-based fishery in seasonal water bodies: Ecological condition of wetlands provides huge potential for the growth and propagation of small edible and ornamental fish species (Nayak and Biswas, 2020).. Farming of small fishes in their natural habitats requires minimal inputs for revenue generation; thereby enabling even the poorer sections of the society to venture into aqua-farming in the periphery regions of the beels. The availability of huge seasonal water bodies and self-help group augurs well for the development of wetland aquaculture.

REFERENCES

Abujam, S. K S., Dakua, S. and Biswas, S. P. (2009), "Physicochemical Parameters and Fish Enumeration of Maijan Beel (wetland) of Upper Assam", *Geobios*, Vol. 36, pp. 184-188.

Abujam, S. K. S., Paswan, G., Deori, D. J., Phukon. H. K., Dakua, S., Biswas, S. P. and Saikia, A. K. (2014a), "Indigenous Poisoning Practice in Water Bodies of NE-India: A Case Study", Fishing Chimes, Vol. 34, No. 4, pp. 34-36.

Abujam, S.K.S.; Shah, R.K.; Deori, D. J. and Biswas, S. P. (2014b), "Diversity of macrophytes in Maijan Wetland, Upper Assam, India", *South Asian Journal of Experimental Biology*, Vol. 4, No.4, pp. 164-171.

Anon (1997), "Wetlands of Assam. Assam Remote Sensing Application Centre, Guwahati" in: G. R. Margarate, M. Obbert, Jr. and C. L. Wolf., *Glossary of Geology*, American Geological Institute, Washington, D. C.

Biswas, S.P. (1996), "Global Water Scarcity: Issues and Implications with Special Reference to India", SIL Proceedings, 1922-2010, 26:1, 115-121, DOI: 10.1080/03680770.1995.11900696.

Biswas, S. P. (2014), Conservation Plan for Aquatic fauna in the Brahmaputra Basin. In: Sinha, R. K. and Ahmed, B. (Eds.) (2014), Rivers for life- proceedings of the International symposium on River Biodiversity: Ganges-Brahmaputra-Meghna River System, Ecosystems for Life, A Bangladesh-India Initiative, IUCN, International Union for conservation of Nature, p. 45-53.

Biswas, S.P. and Michael, R.G. (1992): Fishery characteristics and the present status of Fisheries of the River Brahmaputra. Proc. Seminar on Conservation of River Dolphin in Indian Sub-continent, New Delhi, 18-19 Aug., 1992.

Biswas, S. P.; Baruah, A. and Mohan, R. S. L. (1997): Current status of River Dolphin (Platanista gangetica) in the River Brahmaputra. International Journal of Ecology and Environmental Science, 23: 357-361.

Biswas, S. P.; Baruah, D. and Hazarika, A. (2000), An Experimental Study of Soil Conservation Using Herbaceous Plants in Majuli Island, Assam, India. Environmentalist, 20: 19-27.

Biswas, S.P. and Boruah, S. (2000): Fisheries ecology of the North-Eastern Himalaya with special reference to the Brahmaputra River. Ecological Engineering, 16: 39-50.

Biswas S.P., Boruah, S. and Sharma, A. (2018): Environmental protection of the Brahmaputra River from environment, ecological and legal perspectives. Soochow Law Journal, Taipei 15(2):135-157.

Biswas, S.P., Das, J.N., Sarkar, U.K. and Lakra, W.S. (2007). Ornamental Fishes of North East India-An Atlas. NBFGR (ICAR) Publication, Lucknow, India.

Biswas, S.P. and Das, J.N. (2009). Current status and diversity of ornamental fishes in flood plain wetlands of Upper Brahmaputra basin. In. Wetlands of North-East India: Ecology, Aquatic Bioresources and Conservation (ed.) L. Kosygyn. Akansha Publishing House, New Delhi,p 114-123.

Bordoloi, R., Abujam, S.K.S.and Paswan, G. (2012): Limnological study of a closed wetland- Potiasola from Jorhat District, Assam. Journal of BioInnovation, 1(5):132-141.

Boruah, S., Ganguly, P., Biswas, S. P. and Sharma, A. (2008): Land use land cover changes: Its impact on the wetland Ecosystem of Maguri beel, Assam, India. In. conservation and Restoration (Eds. V. K. Choubey et al.) In national Institute of Hydrology Roorkee, Uttarkhand, p. 605-616.

Boruah, S. and Biswas, S. P. (2001): Restoration of Riverine Ecosystem : A Case Study in the Upper Brahmaputra Basin. In: Ecohydrology (eds. V. Subrahmanian and AL. Ramanathan), UNESCO-IHP Publications, p.17-26.

Boruah, S.and Biswas, S. P. (2002): Ecohydrology and Fisheries of the Upper Brahmaputra Basin. Environmentalist, 22(2): 119-131.

Boruah, S., Gilvear, D., Hunter, P., and Sharma, N. (2008). Quantifying channel planform and physical habitat dynamics on a large braided river using satellite data—The Brahmaputra, India. River research and applications, 24(5): 650-660.

Choudhury, M. and Biswas, S. P. (2004): Ecology and Ichthyofaunal Diversity of Wetlands in Upper Assam. In. Management of Freshwater Ecosystems (ed. L.L. Sharma et al.), p. 73-82.

Choudhury, M. and Biswas, S. P. (2005): Habitat degradation of flood plain lakes of Assam- A great threat to fishery industry in the state. Indian Farming, 55(6): 14-21.

Cornell, H.V. and Lawton, J.H. (1992): Species interactions, local and regional processes, and limits to the richness of ecological communities: a theoretical perspective. Journal of Animal Ecology, 61:1–12.

Cornell, H.V. and Karlson, R.H. (1997). Local and regional processes as controls of species richness. In.D. Tilman and P. Kareiva, editors. Spatial ecology: the role of space in population dynamics and interspecific interactions. Princeton University Press, New Jersey. p. 250–268.

Dakua, S., Abujam, S.K.S., Choudhury, P. and Biswas, S.P. (2009): A preliminary investigation on the fish and fisheries of Maijan Beel in Upper Assam. Indian Journal of Environment and Ecoplanning, 16 (1): 262-270.

Das, A.P. and Biswas S.P. (2018): Aqua ecotourism as conservatory mega tool for depensatory fish germplasm and employment generation. Oceanography and Fisheries, 8(4): 1-2

Nayak, N. and Biswas, S.P. (2020): Wetland Shrinkage: A Threat to the Indigenous Fish Population of Assam.NeBIO, 11(1): 7-8.

Ricklefs, R.E. (1987): Community Diversity: Relative Roles of Local and Regional Processes. Science, 235: 167–171.

Ricklefs, R.E. (2008), "Disintegration of the Ecological Community", *The American Naturalist*, Vol.72, pp. 741– 750.

Rosenzweig, M. L. (1995), *Species Diversity in Space and Time*, Cambridge University Press, Cambridge, U.K.

Sarma, U. and Biswas, S.P. (2012): Studies on Bottom Water Quality and Macrobenthic Community as Bioindicators in the Joysagar Tank, Sivasagar, Assam (India). Journal of Frontline Research Arts and Science, 2: 93-100.