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Sone Beel Wetland in Asia Amidst Global Scenario

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Abstract

Wetlands play an undebatable role in regulating the global climate, hydrological cycle and ecosystem diversity; and, therefore, must be preserved and conserved. Conversely, global wetland area and water quality has since been declining (c 87% around the globe since 1700 AD), mainly due to human interference accompanied by natural succession process. Under this backdrop, physical, chemical, biological and ichthyologic features and fisher folk (following standard procedures of study) of the Asian wetland Sone Beel has been focused as a typical case study in the global scenario. Threats to the ***to Ramsar sites*** *along with their* **categorization** *has also been discussed on a global scenario.*

Keywords

Wetland, Sone Beel, Asia, Globe

1. Introduction

Wetlands play an undebatable role in regulating the global climate, maintaining the global hydrological cycle, protecting the ecosystem diversity, and in safeguarding the welfare of the living world. Therefore, *wetlands must be preserved and conserved* (Hu *et al.*, 2017; Anon 1a i, 2001; Kar, 1984, 2007, 2013, 2015, 2019, 2021 a, b, c, d; Kar & Dimos, 2020; Barman & Kar, 2022; Kar *et al.*, 1996). Wetland ecosystems can certainly bring direct economic values to human beings in addition to many indirect services (Costanza *et al.*, 1997; Smardon, 2009; Kar, 1990, 2013).

Incidentally, it may be mentioned here that, the value per hectare of wetland ecosystem services are said to rank first among all kinds of ecosystems. Also, the total value of wetland ecosystem services are said to account for *c* 47% of the values of the global ecosystem (Costanza *et al.*, 1997; Kar *et al.*, 1996). *Considering various factors, wetland ecosystem is said to be one of the most important and productive ecosystems in the biosphere* (Smardon, 2009; Mitsch & Gosselink, 2015; Kar, 2013, 2019)

Contrary to above, humans, sometimes, instead of attaching importance to the wetlands, consider these precious aquatic domains as habitats and breeding grounds of the mosquitoes, which often act as carriers of disease and leading to death (Giblett, 1996; Anon (2), 2019). Hence, the settlers and the previous governments had tried to reclaim the wetlands and also make full use of their potential (Anon (2), 2019). Notwithstanding the above, the wetland area in the globe has since been diminishing, mainly due to human interference accompanied by natural succession process. Moreover, there had also a decline in the quality of wetland water (Mitsch, 1994). Further, it is believed that, wetlands had degraded by *c* 87% around the globe since 1700; with severe degradation occurring mainly during the 20th and early 21st centuries (Davidson, 2014).

Further, according to OECD (Organization for Economic Co-operation and Development) (Anon (3), 1996), the world had lost *c* 50% of its wetlands since 1900. Concomitantly, the Ramsar (Anon (1 a ii, 2015); Mitsch and Gosselink, (2015) had opined that, the earth had lost more than half of the total number of wetlands mainly during the 20th century. In addition, the Ramsar Convention Secretariat (Anon 1(b), 2010) had also reported a *c* 35% reduction of global wetlands between 1970 and 2015 (Gardner & Finlayson, 2018). This could also lead to a decrease in the value of wetland ecosystem services (Gardner *et al.*, 2015). Therefore, urgent measures are to be taken forthwith to revive the wetland ecosystem health for a healthy and wealthy life on the Mother Earth (Kar, 1990. 2007, 2013, 2019, 2021 a, b, c, d).

2. Human History and Wetlands

Human civilization, since its dawn, has generally been growing in close proximity to water, *viz*., the lakes/wetlands and the rivers. Thus, the importance of wetland environments in the development and sustenance of human cultures is unmistakable; as many cultures in the world, probably, had lived in harmony with the wetlands deriving benefits from them (Nicholas, 1998). Man has been using freshwater for energy production, industrial growth and waste and effluent disposal in addition to using freshwater for drinking, agriculture and transportation. However, human interferences have been degrading the surface water continually. As such, it is essential to know about the impact of the human interference on the wetlands.

Coles and Coles (1989) had dealt with the “wetlanders”, whose cultures were linked with wetlands having being lived in close proximity to them, probably, for centuries. For example, the Camarguais of southern France; the Cajuns of Louisiana; the harvesting of peat or turf in Ireland; peat mining in Estonia; the Marsh of southern Iraq; some Far Eastern cultures; fishermen belonging to various communities living in different wetlands in Asia since time immemorial, notably, about 1,00,000 people have been living in Sone Beel wetland which is the biggest wetland in Assam, India (Kar, 1990, 2007, 2013, 2019, 2021d); about 60,000 people live amid wetland-canal system in Welshan County, Shandong Provinve in China; etc. The “wetland house” in the Ebro river delta region in the Mediterranean sea in Spain is noteworthy. The native Americans in North America had harvested and re-seeded the wild rice (*Zizania aquatica)* along the littoral zone of lakes and streams for centuries; as the Manchurian wild rice (*Zizania latifolia)* are harvested as vegetables in China. Also, the rice fields (wetlands) have been feeding nearly half of the world's population since centuries. Moreover, innumerable number and varieties of plant and animal products are harvested from the wetlands throughout the globe. Further, the Russians, Finns, Estonians, etc., had mined their peatlands for centuries using peat as a source of energy. *Sphagnum* peat is now harvested throughout the world, notably in New Zealand, for horticultural purposes.

3. The Wetland Scientific Literature

The management of wetlands have been discussed in a veritable flood of books, reports, scientific studies and conference proceedings, mostly in the last two decades of 20th century. The huge literature on wetlands could be available in various kinds of records, in conferences proceedings on wetlands; books and articles on wetlands (Niering,1985; Littlehales & Niering, 1991; Mitchell *et al.*, 1992; Kusler *et al.*, 1994; Rezendes & Roy, 1996 on North American wetlands; McComb and Lake, 1990 on Australian wetlands; Kar, 1990, 2007, 2013, 2019, 2021 a,b,c,d on wetlands of the Indian sub-continent and the globe; Finlayson & Moser, 1991; Dugan, 1993).

Notwithstanding the above, the Government agencies and the NGOs around the world have been contributing significantly to the wetland literature and to our understanding of the wetland functions and values. The US Fish and Wildlife Service (USFWLS) had been involved in the classification and inventorisation of wetlands; and, had published a series of community profiles on various regional wetlands. Concomitantly, the US Environmental Protection Agency (USEPA) worked on the impact of human activity on wetlands; as well as, tried to know the possible role of wetland ecosystems in regulating water pollution. Concomitantly, the US Army Core of Engineers (USACE), the USEPA, the USFWLS, the Natural Resource Conservation Service (NRCS), and the Oceans and Watersheds (OWOW), had, probably, collaborated to act as the primary wetland management agencies in the USA.

In addition to above, the Association of State Wetland Managers, the Society of Wetland Scientists, the International Union for the Conservation of Nature and Natural Resources (IUCN), the Ramsar Convention (RC)(the latter two being located in Switzerland) and the Wetlands International (WI) have been developing and disseminating information on management, conservation and various other aspects on wetlands of the world. Incidentally, the WI is a leading non-profit NGO and has a global network of governmental and Non-governmental experts who work on the conservation of wetlands and wetland species. The HQ of WI for Africa, Europe and the Middle East (AEME) is located at Wageningen, The Netherlands. WI works in > 120 countries in the world.

Wetlands are studied by many scientists today. But, only a few pioneers had scientifically investigated these unique systems in detail prior to the 1960s dealing mainly with classical biological surveys or investigations of peat strurcture and peat land hydrology (*e.g.*, in Russia, etc.). Later, workers (in different research centres), like Chapman, Teal, Sjors, Gorham, Eugene and HT Odum and their co-workers had worked by using modern ecosystem approaches in wetland studies. Some of the research centres included the Sapelo Island Marine Institute in Georgia, the Centre for Coastal, Energy and Environmental Resources at Louisiana State University; the Centre for Wetlands at the University of Florida, Pacific Estuarine Research Laboratory at San Diego State University, etc. In addition, one of the leading Wetland Professional Societies is the Society of Wetland Scientists. It provides with a forum for the exchange of ideas within wetland science and also to develop wetland science as a distinct discipline. Moreover, the International Association of Ecology (INTECOL) usually sponsors a major International Wetland Conference at an interval of every 4 years.

4. Literary Reference to Wetlands

Wetlands had, probably, been drained and transformed into agricultural fields, commercial and residential complexes prior to the mid-1970s, based, probably, on specific US government policies. But, this practice had to be stopped short based on issues being raised unanimously by the anglers and hunters, scientists and engineers, lawyers and environmentalists, and so on, for the protection, conservation and sustenance of these precious and indispensable natural resources, whose absence could lead to economic, ecological and aesthetic consequences for the globe. Being cautious and conscious at this unanimous clarion call there had been signs of respect in the US Public policy for the wetlands, which was reflected in the activities, such as, the sale of federal “duck stamps” to waterfowl hunters which began in 1934. Countries, like New Zealand (NZ) had followed suit. Consequently, *c* 1.8 million ha of wetlands were preserved as waterfowl habitat during 1995 by the US duck stamp programme alone. Other ambitious programmes by the federal government also followed suit for the protection of wetlands; followed by individual States enacting wetland protection laws or using/updating existing statutes to preserve these valuable resources. Gradually, the locally-developed interest in the US during the late 1970s, had spread round the globe leading to initiation of International Programmes, such as, the Ramsar Convention, dedicated to the conservation of the wetlands.

4.1 Sone Beel Wetland in Asia: A Typical Case Study

4.1.1 Materials and Methods

Fish samples were collected through experimental fishing using caste nets (dia.3.7 m and 1.0 m), gill nets (vertical height 1.0 m- 1.5 m; length 100 m -150 m), drag nets (vertical height 2.0 m), triangular scoop nets (vertical height 1.0 m) and a variety of traps. Camouflaging technique was also used to catch the fishes. Fishes have been preserved at first in concentrated formaldehyde in the field itself and then in 40 % formalin. Fishes have been identified after standard literature (Day, 1878, 1889; Shaw & Shebbeare, 1937; Misra, 1959; Menon, 1974, 1999; Talwar & Jhingran, 1991; Jayaram (1981, 1999). Yield statistics were extrapolated (Dey & Kar, 1990; Kar, 1990) from daily catch statistics recorded at the landing stations (FAO, 1974) while the trend and cyclic variations were constructed by applying 12 months moving average method (Coxton & Cowden, 1950; Kar & Dey, 2000). Limn logical studies have been done following American Public Health Association (APHA, 2019), Welch (1948), Wetzel (2001), Kar (2007).

4.2 Results

A Limno-ecological investigation conducted on the 3458.12 ha (at Full Storage Level) Sone Beel (92º 24' 50" E and 24º 44' 30" N) (Figures 1, 2, 3) in the Karimganj district of Assam revealed the tectonic origin of the wetland. The impact of post-tectonic activities was also discernible from its shallow plate-like basin characteristics supplemented with low volume development (0.15). The biggest wetland in Assam (which is sometimes popularly called a lake) had a long shoreline of 35.4 km, a shore development of 1.69, a gross volume of 101.54 x 10^6 m^3 and a mean depth of 0.29 m. The wetland, which diminished to 409.37 ha at Dead Storage Level (DSL), has continuous inlet (max. flow 33.91 m^3 sec^{-1}) and outlet (max. Flow 87.03 m^3 sec^{-1}) channels. The outlet, River Kachua, acted as a spillway to limit retention of excess water storage. The study exhibited retention of higher silt load in the wetland through the inlet (max. 350.0 mg $lit.^{-1}$) in contrast to low expulsion through the outlet (max. 216.0 mg $lit.^{-1}$). The turbidity ranged from 20.56 TU to 185.54 TU while the overall thermal trend of the wetland depicted a state of isothermy with a bimodal peak occurring during summer and monsoon. The water temperature varied from 18.7 to 32.3 º C and it followed the air temperature fairly closely. The water of Sone Beel wetland was circumneutral with pH varying from 6.02 to 7.9, DO ranging from 2.6 to 5.9 mg $lit.^{-1}$, FCO_2 fluctuating from 0.9 to 14.5 mg $lit.^{-1}$ and TA lying between 25.0 to 76.0 mg $lit.^{-1}$. The solubility of DO ranged from 9.4 to 11.9 mg $lit.^{-1}$ while it % saturation varied from 32.3 to 74.4%. DO portrayed an inverse relation with temperature and FCO_2, but a direct with pH and TA. As an index of dissolved salts, the conductivity of Sone water was low. The wetland soil was quite unproductive with pH ranged from 5.02 to 5.9, Organic Carbon (OC) 0.25 to 1.74 %, available phosphorus varied from 0.15 to 1.93 mg 100 g^{-1} and available potassium 1.62 to 24.8 mg 100 g^{-1}.

The phytoplankton played the major role in the yield of total plankton, being represented by 47 forms under 7 families. Phytoplankton density varied from 10 to 5308 units $lit.^{-1}$ with chrysophytes being the most dominant and pyrrophytes the least. The zooplankton contained 19 different forms with the density ranging from 6 to 380 units $lit.^{-1.}$ The copepods and cladocerans were the most dominant and the protozoans, the least.

The distribution of heterogeneous assemblage of aquatic macrophytes (AM) in the wetland was found to be mostly influenced by depth level (DL) and duration and amplitude of flooding. The AM biomass varied form 0.50 to 21.90 kg m^{-2} while *Eichhornia crassipes*, *Hydrilla verticillata* and *Trapa bispinosa* were the most dominant species recorded throughout the year. And, the littoral fauna, represented by both piscian and non-piscian groups exhibited biomass of the former ranging from 0.05 to 1.53 g m^{-2} while that of the latter from 1.6 x 10^{-4} to 1.09g m^{-2}.

Of the 70 ichthyospecies belonging to 49 genera under 24 families, 84.2 % belonged to primary freshwater group while the rest were of peripheral class. The average annual total fish yield (FY) from the wetland was estimated as 335.18 metric tonnes. The trend thereby showed average per hectare yield of 96.88 kg. Significantly, *Puntius chola,* the minnow, contributed to bulk of the lake fish landing registering an average Annual Relative Yield(ARY) of 24.60 %. While the Indian Major Carps (IMC) depicted an average ARY of 0.73 %, *Labeo rohita* portrayed average ARY of value of 0.235 %, which, incidentally, was the highest amongst all the species of the group. And, among all the predators with average ARY as 3.29 %, *Wallago attu* alone constituted average ARY of 2.94 %. The Indian shad, *Hilsa (Tenualosa) ilisha*, with an ARY of 0.04 %, revealed a single run during the monsoon against two runs in other water bodies of India.

Out of the four principal fishing communities of the wetland, classified into occasional, part-time and professional types, the "Kaibarta" community constituted 68 % of the total fisher folk and 55 % of the Kaibarta fishermen were professional.

Among the 26 varieties of fishing gears recorded, Mahajal, Daljal and Chatjal were the monsoon varieties while the hooks and lines, the cages and large-meshed cast net were operated chiefly during the winter. The gill net and the triangular scooping net had no seasonality. The CPGH (Capture or catch person^{-1}.gear^{-1}. Hour^{-1} : Dey, 1981) of Mahajal was the highest (1.28 to 1.69 kg) followed by Chinese dip net (0.53 to 0.93 kg), long line (0.52 to 0.68 kg), cage trap (0.21 to 0.56 kg), and gill net (0.14 to 0.21 kg).

The present investigation, being the first of its kind from this biotope, shall help portray a coherent picture of the wetland fishery in Asia in general, and the Indian sub-continent in particular (Kar, 1984, 1990; 2007, 2013, 2019, 2020, 2021 a,b,c,d; Kar *et al.*, 1996).

4.3 Discussion

Fish production in shallow wetlands, including rice fields have been in practice in many SE Asian countries, notably in China, India, and in sub-Saharan Africa, etc., since centuries; and, could be important source of protein. Harvest of crayfish is practiced in the wetlands of Louisiana and the Philippines even today. Moreover, the coastal marshes are used as pastures for grazing and for hay production in northern Europe, the British Isles, New England, etc. In addition, the coastal mangroves are harvested for timber, food and tannin in Indo-Malaysia, East Africa, Central and South America, etc. Reeds and muds from the inland and coastal wetlands are used as fencing material, thatching of roofs, wall construction, etc., in Europe, Iraq, Japan, India, China, etc.

4.3.1 Threats to the Ramsar Sites

None of the wetlands in the globe could be said to be in safe hands today with regard to their very existence. Impact factors of wetland could be classified into wetland transformation and wetland destruction (Mitsch & Gosselink, 2015). Dereliction and degradation of many of the wetlands could be attributed to the destructive factors, such as, bad and often harmful agricultural practices; infrastructure development ; use and often abuse of water; pollution; and, so on (Gardner & Finlayson, 2018; Anon (1) b i, 2010; Anon (4), 2015; Vörösmarty *et al.*, 2010; Van Asselen *et al.*, 2013). Probably, *c* 56% to 65% of the wetlands in Europe and North America were drained for agriculture by 1985(although, a different view suggests drained during the first half of the 20th century); which were *c* 27%, 6%, and 2%, respectively in Asia, South America, and Africa (Smardon, 2009). Incidentally, wetlands in the tropical and subtropical regions had been largely degraded or lost, due to the conversion to agricultural use since the 1950s ((Anon (3), 1996; Niu, 2011). In fact, the total loss of wetlands due to agricultural practices is said to be *c* 26% in the globe (Anon (3), 1996; Anon (5), 1999; Revenga, *et al.*, 2000). The use of water for various purposes is said to be another major cause for inland wetland degradation.

Notwithstanding the above, wetland loss, thus, refers to the actual area loss of the wetland, which could be due to human interference and/or due to climate change. Moreover, burgeoning population growth coupled with economic developments have been having significant bad impact on the wetlands (Gardner and Finlayson, 2018; Anon (6), 2005; Anon 11 (b), 2001). However, there had been unanimous and concerted efforts by the local, regional and national organizations coupled with international cooperation to protect these coveted wetlands (Gardner *et al.*, 2015; Gardner & Finlayson, 2018). Further, efforts are made to use the incidence of impact factors to reflect the threats of various factors to the wetlands.

A Ramsar Site means a wetland reserve. The area of a Ramsar Site and the actual area of a wetland in a site may not be the same; because, they are based on two different concepts. Usually, the area of a Ramsar Site will not alter unless it is expanded, adjusted, or merged with other protected areas ((Anon (11a), 1992; Zheng *et al.*, 2012).

According to Taub (1984), all rivers in Japan had constructed artificial lakes in order to meet the growing demand for water. However, these lakes had lost *c* 80% of their capacity due to the siltation problems. Moreover, pollution due to burgeoning growth of population coupled with socio-economic development, is said to be also a major factor in leading to wetland degradation and loss (Gardner & Finlayson, 2018; Anon (7 a), 2012; Anon (8), 2012; Michalak *et al.*, 2013; Anon (9), 2015; Anon (10), 2016.; Anon 7(b), 2017). Eventually, this might had led to the degradation of the wetlands associated with loss of economically important species and concomitant invasion by the weeds (Muñoz-Reinoso, 2001).

4.4 Categorization of the Threats

There are different types of threats to the wetlands across the globe due to various factors. Out of these, the impact on the land area is the most serious, occurring in *c* 75% of the surveyed sites. Incidentally, the percentage of affected wetland sites in five continents (except Europe) are said to be > 80%; while, that of Europe is as high as 65%. The impact on the wetland soil is reflected mainly by encroachment /occupation of wetland area for agriculture and aquaculture; natural system modifications (including vegetation clearance/land conversion and dams and water management/use); human rehabilitation/settlements; and, transportation and service corridors construction, etc.

However, the impacts leading to natural system modifications occurred seriously in *c* 53% of the sites followed by the impact caused due to agriculture and aquaculture (*c* 42%), and human settlements (*c* 34%). Impacts leading to natural system modification(s) could be due to land encroachment, habitat destruction, etc. Such types of impacts are prominently found in Oceania (*c* 68%, distributed in the regions along the SE coasts and the Darling River); Africa (*c* 65%, distributed in the regions along the west and SE coasts, the Lakes Victoria, Tanganyika, Chad; the Rivers Niger, and Zambezi); and, North America (*c* 61%, distributed in the SW coast of Mexico).

Concomitantly, the regions with greater impacts due to agricultural and aquaculture practices and concomitant land occupation for those purposes, are Africa (*c* 60%, distributed in the regions along the north coasts and the River Niger); South Africa (*c* 51%,distributed in the regions along the west coasts); North America (*c* 46%, distributed in the SW coasts of Mexico); and, Asia (*c* 46%, distributed in the regions along the Rivers Indus, Ganges, Brahmaputra and Barak associated with their tributaries in the Biodiversity hotspot regions).

Further, the regions more seriously affected by human settlements are North America (*c* 48%, distributed in the SW coasts of Mexico), Africa (*c* 44%, distributed in the regions along the NW coast); and Asia (*c* 40%, distributed in the regions along the River Indus; significant percentage along the Rivers Ganges, Brahmaputra and the Barak, etc.; the south and east coasts).

Last, but not the least, the regions more seriously affected by transportation and service corridors are South America (*c* 30%, distributed in the regions along the west coasts).

Concomitant to above, the impact on the wetland environment (in general) is also a major factor; which could be caused due to pollutants coming from household sewage, urban waste water, garbage and solid waste, agricultural and forestry effluents, and industrial effluents, recreational and tourism activities, etc. These conditions are pronounced especially in South America and North America, where *c* 75% and *c* 74% of the wetland sites respectively are affected. Concomitantly, these figures in the other four continents are >60 %.

The human intrusions and disturbances could also exert impacts on the wetland environment. In this context, the situation in Europe (*c* 41% distributed along the coast and along Rivers Danube and Rhine) and South America (*c* 34 % along the NW coasts) and a extensive siltation of the wetlands and rivers in India and Asia are not encouraging. In addition, energy production and mining activities also exert some amount of impact on the wetland environment; and, such type of impacts are said to be *c* 35 % in the regions along the west coast of South America.

Innumerable wetlands are also affected by overuse of biodiversity resources; especially in Africa (*c*71%), South America (*c* 68%), and North America (*c* 56%). Asia, in this regard, probably, is not lagging behind, having being lost innumerable precious God-given wetlands along with their coveted bio resources. Exotic, invasive and problematic genetic resources pose serious threat to the wetlands and the native species; with *c* 62% of the wetlands in Oceania and numerous wetlands in Asia having been affected by such issues. In this regard, it may be mentioned here that, numerous Indian wetlands are subjected to threat of dereliction and extinction due to the invasion by exotic and invasive *Eichhornia crassipes* (Kar, 1990, 2007, 2013, 2019).

Works revealed that, the water of *c* 30% to 50% of the wetlands in almost all the continents have been affected with more impacts having being found in many wetlands in Oceania (mainly distributed in the regions along the Murray River) and Europe (mainly distributed in the regions along the rivers Rhine, Danube, the Vanern Lake, and most coasts). Australasia is the continent generally with less precipitation with much uneven spatial and temporal distribution of the rainfall. Thus, here, the actual availability of total water resources is less; although, the need for water resources per capita in Australia is large. So, the demand is high mainly due to increasing water consumption by burgeoning population growth, Thus, a large number of water conservancy projects need to be built-up in Australia in order to regulate water storage (Pigram, 2007). Concomitantly, the increasing use of water for agriculture and tourism in Europe could lead to scarcity of water at some point of time.

Notwithstanding the above, some wetlands, particularly, some of the marine/coastal ones (*c* 41%) and some marshes (*c* 23%) are affected by climate change and extreme weather conditions, geological disasters, etc. (Anon 11 (a),1992. Anon 11(b), 2001).

From the point of latitude zoning, the most affected region is 40°S–50°S (*c* 56% of the wetland sites in this area have been affected by climate change and severe weather conditions, and, it is mainly distributed in the SE area of Oceania.); followed by 10°S–20°S (*c* 28%, of the wetlands in the north regions of Oceania and the SE areas of Africa.); followed by 10°N–20°N (*c* 28%, mainly distributed in the NE regions of Africa and Mexico); followed by 20°S–30°S (*c* 20% of the wetlands, probably, affected), and, followed by 30°N–40°N (*c* 19% of the wetlands distributed mainly in Central Asia, the Tibetan Plateau regions of China and the coastal regions of Japan, and the arid climatic zones in northern Africa). It may be noted here that, in Oceania, 30 out of 72; in Africa, *c* 105; in Europe, *c* 85; and, in Asia, *c* 71 wetland sites are affected by climate change and extreme weather condition. However, the wetlands affected by geological events are mainly the marine/coastal wetlands (*c* 62%) and inland alpine wetlands (*c* 26%).

Notwithstanding the above, the riverine wetlands are said to be most affected by encroachment and occupation of land belonging to the wetlands (*c* 87%) coupled with loss of biodiversity. On the other hand, the types most affected by water resources regulation are marsh wetlands (*c* 45%).

Interestingly, *c* 63% of the sites in the United Kingdom (UK) and *c* 44% of the sites in Ireland were, probably, have not been much affected. However, *c* 24% of the sites in the UK and *c* 49% of the sites in Ireland are threatened by only one or two factors. The water regulation and pollution are the main factors affecting wetlands in the UK; while, pollution and agricultural use are the main factors affecting wetlands in Ireland.

4.5 Levels of the Impacted Wetlands

Out of more than half of the sites affected by three or four impact factors (*c* 55%), Oceania is said to be having reached a serious stage (with levels 3 and 4) contributing to *c* 68%, followed by North America (*c* 63%) and South America (*c* 63%), as revealed from the results of classification (Anon (1 b ii), 2010; Anon (5),1999). Concomitantly, the proportions of levels 3 and 4 of other continents are *c* 60% in Africa, *c* 51% in Asia, and *c* 50% in Europe. Incidentally, the UK and Ireland represent many of the the unaffected sites (level 0). Further, the sites affected by one impact factors (level 1) are also located mainly in the UK, Ireland, Spain, and Denmark in Europe; Togo in Africa; China and South Korea in Asia; Canada and Mexico in North America.

Notwithstanding the above, it may be noted here that, about one-third of the wetland sites have been artificially re-constructed, which may have adverse effects on the ecology of the wetlands. Incidentally, the proportion of natural wetlands which are unaffected or affected by only one factor are generally higher than the human-made ones (*c*11% for inland wetlands and *c*12% for marine/coastal wetlands). Such proportionate differences for the various continents, like Africa, Asia, Europe, and North America are *c* 9 and 11%, 18 and 12%, 17 and 16 %, 6 and 16 % respectively; while the proportionate differences are *c*14% for marine/coastal wetlands in South America; and, *c*10% for inland wetlands in Oceania.

Notwithstanding the above, it may be noted here that, wetland conservation in China is in a transitional phase; and, wetland restoration and re-construction projects have been, of late, vigorously carried out. Incidentally, *c* 42 % of the inland wetland sites and *c* 38% of the marine/coastal wetland sites have been artificially re-constructed or altered. Notably, the area of human-made wetlands accounts for *c* 50%, of the 20 typical Ramsar Sites in China, monitored by the NRSCC. However, there are significant limitations in maintaining the overall ecological function of the wetlands.

4.6 Degradation and Threats of the Typical Ramsar Sites

The degradation and threats of some of the wetlands areas in certain countries and
continents are briefly discussed below:

4.6.1 Asia

Monitoring of 20 Ramsar Sites in Asia by the NRSCC during 2014 had revealed reduction in the total area of these 20 wetland sites by *c* 1% between 2001 and 2013. Concomitantly, the total water area and the landscape integrity had also portrayed decreasing trends. Insufficient water supply and climate change, probably, were the reasons for the dereliction of the wetland ecosystems (Anon (12), 2014). The area of the wetlands in Sanjiang Plain (the largest natural marsh wetland site in China) had decreased alarmingly by *c* 79.4% (*c* 2.99 million ha) from 1954 to 2015, mainly due to agricultural reclamation (Zhao *et al.*, 2008; Yan *et al.*, 2017).

Notably, the main cause of the loss of water spread area of the natural wetland(s) is said to be their transformation into agricultural land; while, the principal reason for wetland degradation is, probably, the decrease in wetland water level due to decrease in groundwater level. Concomitantly, Lake Urmia is one of the largest permanent high salinity lakes in the world. Its area decreased by *c* 40% between 2001 and 2013; while, *c* 49% of flooded wetlands were converted into artificial surfaces or bare land (Anon (12), 2014). Incidentally, the Mekong River basin includes many Ramsar Sites in South Asian countries. Notably, the lack of coordination in river basin management in these countries, especially in the wetland management of the Mekong Delta region, could be mainly responsible for the dereliction of such precious water bodies. Of late, the wetlands in the Mekong River Basin have been threatened by many factors, such as, agricultural intensification, urbanization, industrialization, and so on. However, the most significant factor is said to be the construction of dams and reservoirs (Mitsch and Gosselink, 2015).

Concomitant to above, Sone Beel is one of the biggest natural wetlands in India and Asia. Unhappily, there have been an alarming shrinkage of its Full Spate Level (FSL) waterspread area from. 6774.0 ha in 1880 to 3458.12 ha during 1980. Further the present 3458.12 ha (at FSL) further shrinks to 409.37 ha at Dead Storage Level (DSL); thus, 3048.75 ha of the water spread area lost to oblivion; mainly due to

Siltation followed by encroachment and agricultural practices. It may be unhappily noted here that, the siltation process has been fast aggravated due to the construction of a blind dam on the outlet (River Kachua) during the 1950s in order to mitigate flood problems. This had prevented the flushing-out of the large amount of silt (brought-in into the wetland by the rheophilic (hill stream) inlet, River Singla (maximum silt load max. 350.0 mg $lit.^{-1}$) originating and flowing down from the Mizo Hills (*c* 374 m MSL). Concomitantly, the maximum silt load in the flushed-out outlet water of River Kachua was 216.0 mg $lit.^{-1}$; thus, clearly indicating the retention of much amount of silt in the wetland; thereby, decreasing the waterspread area and the depth of the wetland. Although the blind dam had been replaced by a lock gate in the year 1964; there had been no let up in the situation; mainly because of improper and irregular operation of the lock gate. Incidentally, considering the high potential of Sone Beel, this wetland has been declared as a `Wetland of National Importance' by the Government of India based on the detailed, in-depth, original research works done by Professor Dr Devashish Kar in this coveted aquatic domain since 1975 (*vide* Resolution No. 11 dt. 16.10.2008 of the Meeting of the Expert Group of MOEF, Govt. of India, New Delhi; and Letter No. FRM 41/2008/63-A, dt. 8.9.2008 from Commissioner and Secretary to the Govt. of Assam, Department of Environment and Forests). (Kar, 1984, 1990, 2007, 2013, 2019, 2021 a,b,c,d).

4.7 North America

There are quite a big number of wetlands in North America. Incidentally, the Everglades National Park is said to be the largest Ramsar Site among the primitive wetlands in the United States. About half of the original Everglades had vanished; mainly due to agricultural practices in the North and urban development in the East and West (Mitsch & Gosselink, 2015). However, a series of protection measures had been taken-up, of late, aimed at restoraton of natural water flow in this area; and, satisfactory results had been obtained (Anon (12), 2014).

Concomitantly, San Francisco Bay is one of the most important ecological estuaries in North America and one of the most altered and urbanized wetland areas in the United States. Incidentally, *c* 95% of the wetlands had been lost since the first European settlers had arrived. They had invaded the wetland; at first, to develop agriculture; and, later, to make salt industry. They had cleared the vegetation; built dykes to drain out the wetland water; and, eventually, this had led to rapid degradation of the wetlands. Later, the erosion and deposition caused by upstream hydraulic mining are also said to be big threats to the wetlands (Mitsch & Gosselink, 2015). Further, the wetland ecosystems in Queen Maud Bay, distributed in the polar tundra with less human disturbance, had also gradually deteriorated; suggesting that, climate change could be one of the significant impact factors (Anon (12), 2014).

4.8 South America

The total wetland area of 20 Ramsar Sites in South America had reduced by *c* 0.26 million ha between 2001 to 2013 covering the marshes and lakes, as revealed from NRSCC`s research. The degeneration of the wetlands and the transformation of swamps into artificial surfaces or bare land were said to be impacted mainly by human agricultural activities; as well as, due to alteration(s) in the precipitation patterns (Anon (12), 2014). This, probably, had caused acute water scarcities. Incidentally, the Lake Mar Chiquita is one of the biggest saline lakes in the world. Its area had reduced by *c* 26%; while, on the other hand, its dry land area had increased by > 2 times between 2001 and 2013. Concomitant to above, Pantanal is one of the biggest wetland complexes in the world. This includes many inland Ramsar wetland types in South America. The Pantanal Matogrossense is a part of this complex; and, is a permanent freshwater wetland in the Western Hemisphere (Anon 1 (d), 2018). Incidentally, with the development of the upper Paraguay River, Pantanal has been threatened by many elements. This included, among others, the encroachment for pastoral and agricultural land use, water pollution caused by mining activities, and the invasion by alien species. Moreover, Pantanal had, probably, become a place for illegal wildlife trafficking and cocaine smuggling, mainly because of its remoteness; and, thus, wetland management had become difficult and expensive (Mitsch & Gosselink, 2015)

4.9 Europe

The total wetland area of 10 Ramsar Sites in Europe had been reduced by *c* 3% between 2001 to 2013, covering mainly the marshes and lakes, as portrayed in NRSCC`s research. In fact, *c* 12 % of the reservoirs and *c* 34% of the seasonal marshes had been degraded into non-wetlands; and, the interference degradation index had increased significantly, which may be related to long-term wetland development programme(s) in Europe (Anon (12), 2014).

Incidentally, the Lake Sevan is one of the largest alpine freshwater lakes in the world. Notably, the agricultural areas in the region had increased by *c* 10%. Moreover, excess groundwater extraction, probably, had posed a big threat to the lakes. Incidentally, the lakes had been artificially replenished since 2001, Also, *c* 17% of the forests and shrubs had been submerged, due to the replenishment. Moreover, it had brought about ecological problems, such as, organic pollution and depletion in fish production (Anon (12), 2014). Notably, the Danube Delta is one of the biggest and most natural inland deltas in Europe. It includes a number of Ramsar wetland sites in Europe, which are said to be degraded due to drainage and activities related to agricultural development, gravel mining, and dumping (Mitsch & Gosselink, 2015; Anon 12 (2014); Coleman, 2008).

Major international studies had been carried out in the delta; and, most of the recovery process is simple; in the form of just restoration of natural hydrology by dams and re-connecting waterways (Mitsch & Gosselink, 2015). Incidentally, the Volga Delta, is said to be one of the largest inland deltas in the world, which is situated on the edge of the Caspian Sea. However, the wetland is now affected by a number of impact factors. These include dam damage affecting the river's natural hydrology; pollution from heavy industries and agriculture, and the decline in the level of the Caspian Sea (Mitsch & Gosselink, 2015; Coleman *et al.,* 2008).

In addition to above, the Wadden Sea, contains many significant Ramsar coastal wetland sites in Western Europe. Incidentally, a myriad of wetlands had been under cultivation by the local residents over the past few centuries (Mitsch & Gosselink, 2015)

4.10 Africa

The continent of Africa is rich with many wetlands. However, there had been a reduction of *c* 2000 ha of water spread area in *c* 30 Ramsar wetland Sites in Africa; as revealed from NRSCC`s research. But, wetland ecosystem degeneration is said to be more serious. Further, *c* 17 % of the riverine wetlands and *c* 20% of the inland floodplain wetlands had been degraded into land. Concomitantly, many other wetland types had also been degraded. Thus, the disturbance degradation index in Africa was high and kept on constantly increasing (Anon (12), 2014).

Incidentally, the Lake Chad, an African transnational lake, had suffered *c* 9% reduction in lake surface and *c* 89% decrease in the area of seasonal herbaceous swamp between 2001 to 2013, mainly due to drought and drainage irrigation (Anon 12 (2014). In this regard, the signal site (the biggest area) is the Ngiri-Tumba-Maindombe, located in the Democratic Republic of Congo (DRC) in Africa (Anon 1 (c), 2018). Now, the said region is under apparent threat because of the growing population pressure and unlawful activities (Anon 1 (d), 2018). Incidentally, the DRC is said to contain the largest number of Ramsar wetland sites in the world (Anon 1 (c), 2018).

Nevertheless, the Ramsar Sites in DRC are said to play a pivotal role in the conservation of rare and endangered biota of the region. These are said to be some of the last remaining sites in the country where human intervention and exploitation of natural resources are not permitted. However, long duration civil war and political unrest in the country had adversely affected these natural habitats and their biota; and, the fauna had been affected due to unlawful human activities. Thus, there is a need for urgent international attention to protect these fragile habitats (Anon, 1 (c), 2018; 1 (d), 2018).

Concomitant to above, the Okavango Delta System is one of the largest Ramsar wetland complexes in the world (Anon, 1 (c), 2018). However, it now faces a number of threats; mainly from increased burning; as well as, due to interception of water resources by the upstream countries` tourism threats, raw materials overuse, etc. (Mitsch & Gosselink, 2015).

Incidentally, Okavango’s fire is natural. Further, the important Mangrove Swamps in West Africa are distributed in many Ramsar coastal wetland sites; which, however, are said to be gradually eroded due to drought and desertification, causing also reduction of persistent water bodies (Mitsch & Gosselink, 2015). Concomitantly, it is also threatened by over exploitation and conversion into rice fields (Mitsch & Gosselink, 2015; Anon, 1 (c), 2018)

4.11 Oceania

The oceanea is rich in wetlands. However, there had been reduction in the wetland area by *c* 80,000 ha, between 2001 and 2013,in two Ramsar Sites in Oceania, as reflected from the studies of NRSCC. Moreover, *c* 90% of the seasonal marshes were degraded into forest shrubs. Therefore, the disturbance degradation index of Oceania was said to be the highest among all continents (Anon (12), 2014).

Incidentally, the Kakadu National Park is said to be the largest National Park (NP) in Australia. Incidentally, a large number of wetland ecosystems had degenerated, between 2001 to 2013; and, some of the wetlands had been converted into artificial surfaces or bare land (Anon (12), 2014).

In addition, the Shoalwater and Corio Bays are said to be significant areas in east Queensland. The site is important; because of the only remaining remnant of its type, size, and condition in central Queensland. Incidentally, the main threats to the region include pollution, erosion, pests, and inappropriate recreational use (Mitsch & Gosselink, 2015). Furthermore, the Whangamarino is the second largest peat bog and swamp complex in the North Island. Its main threats are the reduction of river flooding, the deposition of silt caused by agricultural development, the increase of fire frequency, and the invasion by exotic species (Mitsch & Gosselink, 2015; Anon (12), 2014).

Thus, these typical wetland sites, had suffered loss of area and ecosystem degeneration. Incidentally, human activities are said to be the main impact factors coupled with alteration(s) in climate which, probably, also has certain amount of impacts on the wetlands.

Notwithstanding the above, fish production in shallow wetlands, including rice fields have been in practice in many SE Asian countries, notably in China, India, and in sub-Saharan Africa, etc., since centuries; and, could be important source of protein (Kar, 2013). Crayfish are harvested in the wetlands of Louisiana and the Philippines even today. Moreover, the coastal marshes are used as pastures for grazing and for hay production in northern Europe, the British Isles, New England, etc. In addition, the coastal mangroves are harvested for timber, food and tannin in Indo-Malaysia, East Africa, Central and South America, etc. Reeds and muds from the inland and coastal wetlands are used as fencing material, thatching of roofs, wall construction, etc., in Europe, Iraq, Japan, India, China, etc. (Kar, 2013).

It may be noted here that, of the vast array of freshwater lentic systems throughout the globe, very few have received adequate attention from the limnologists. Also, those which have been studied are, for the most part, confined to restricted geographical regions. The inland lentic systems, distributed along the length and breadth of Asia, Africa, America, Canada, Europe and Australia present wide open opportunity for doing in-depth immunological research. The diversity of these lentic systems, physically, chemically and biologically, are infinitely greater than previously supposed.

The Wetlands have been serving the humanity since time immemorial. They have been undergoing changes loosing their pristine character mainly due to human impacts. Ramsars Convention had framed many guidelines for wise use of the Wetlands. But still there have been not much let up in the situation. Wetlands have been degraded severely with the consequence of threats to the sustenance of human civilization.

5. Conclusion

Water is a basic substance on which the dynamics of a water body and thereby the life of the biota in it depends. To a limnologist, fishery scientist and a fish farmer, study of water is a pre-requisite for the welfare of the fishes and to know their environment. The important wetland ecosystems serve as sources, sinks and transformers of a multitude of chemical, biological and genetic materials; and, they are also valuable for fish and wildlife protection.

Among the vast array of freshwater lentic systems in the world, very few have received adequate attention from the limnologists. Also, few researched wetlands are, for the most part, confined to restricted geographical regions. The inland lentic systems, distributed along the length and breadth of Asia, Africa, America, Canada, Europe and Australia present wide open opportunity for doing in-depth limnological research. The diversity of these lentic systems, physically, chemically and biologically, are infinitely greater than previously supposed.

Wetlands still, perhaps, remain as an enigma to the scientists even after their ecological and economic benefits were determined and became widely appreciated too. They are sometimes difficult to define precisely, not only because of their great geographical extent, but also because of the wide variety of hydrologic conditions in which they are found. The wetlands have occupied a position between the cracks of the scientific disciplines of terrestrial and aquatic ecology because they have combined attributes of both aquatic and terrestrial ecosystems, but are neither.

Understanding of aquatic life requires knowledge of the external influences which directly or indirectly affect the organisms. Moreover, there is need for a multidisciplinary approach and knowledge in a number of fields in wetland investigations, notably, proper management policy for the conservation of these precious ecosystems for the welfare of the living beings on the earth.

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