Chapter - II
REVIEW OF LITERATURE

Studies on wetlands gained momentum during the last few decades only, but during this short span of time a number of studies have been done all throughout the world. With the publication of an ample amount of work, people all over the world have become conscious and aware on the importance of wetlands in terms of their role in conservation and environment.

Environmental Protection Agency featured about the importance of wetlands and reported wetlands as the most productive ecosystems in the world, comparable to rain forests and coral reefs [13].

Mitsch et al. suggested that a range of 3–7% of temperate-zone watersheds should be in wetlands to provide adequate flood control and water quality values for the landscape [25]. Thus stated that the wetlands appear to work properly in the landscape where the wetlands are spatially distributed.

Evans et al. reviewed the functions of wetlands to improve water quality. The study explains how wetland type and location influence water quality, and it reviews the cases for development or preservation [26]. They indicated that some wetlands impede drainage flow from developed land, filter out pollutants and greatly improve the quality of the water entering streams; others provide no significant water-quality benefits. They supported the preservation and restoration of riparian areas close to the streams. Moreover the study revealed to improve the water quality and some inter stream divide wetlands could be developed to compensate for croplands restored as riparian wetlands.

According to a study carried out by Green Heritage, an NGO of Assam, the geographical location of Lakhimpur district has enhanced the entire area as a suitable location for a large number of residential as well as migratory birds [27]. The riverine sand bars and islands of the river Brahmaputra and its numerous tributaries like Subansiri, Ranganadi and its innumerable fresh water lakes (locally called *beel*), or ox-bow lakes (*era suti*), marshy tracts and seasonally flooded plains creates an ideal wetland ecosystem, which serve as a rare refuge for a large number of water birds, including some rare and Red Data Book species. In Lakhimpur district of Assam, the number of wetlands are 151(3033.50 ha). According to Flood Report, Lakhimpur district is one of the highly flood ravaged districts of Assam. Every year flood inundates huge area of the district with unimaginable threats to life and property of people. To compensate the flood damaged, the District Agriculture Department, Lakhimpur has worked out contingency plan for the said district separately based on their land situation and climatic condition.

A study made in Uganda by Kansiime, et al. reported different forms of human pressure on wetlands and in order to develop sustainable management tools for the wetland ecosystems in the country a comparative study on water quality were carried out in a rural undisturbed (pristine) wetland (Nabugabo wetland in Masaka) and two urban wetlands that are experiencing human and urban development pressure (the Nakivubo wetland in Kampala and Kirinya wetland in Jinja) [28].

Kiran et al. studied on the status of wetlands in Bangalore and its conservation aspects. The main objective was to identify major pollution problems of Bangalore wetlands and suggest suitable measures for restoration and management of wetlands [29]. To initiate the study the authors collected sufficient information on the various functions, components and attributes of wetlands to reduce the ongoing ecological imbalance Water quality assessment of seven water bodies located at various places in Bangalore urban district has been monitored for a period of twelve months and based on the findings of the study, suitable restoration measures are suggested. They proposed some of the management practices like assignment of designated use, creation of buffers zones for wetlands protection, community involvement, training and awareness programs in schools and colleges and regulatory agencies consisting of representatives from local community and the concerned agencies are to be made responsible for developmental activities.

Madhya Pradesh is very rich in wetlands and the aquatic biodiversity is very high. Hence a study on the status and conservation of aquatic species diversity in certain water bodies of Madhya Pradesh was done by R.J Rao [30]. The findings showed that out of the total geographical area of Madhya Pradesh (443446 sq.km.), wetlands greater than 56.25 ha. (407 in number) cover 294118 ha. (0.066%), while wetlands smaller than 56.25 ha. are 1476. Majority of the wetland area is under man-made category, which account for 266864 ha. The water reservoirs and village ponds apart from meeting the requirement of water for agriculture, industry and drinking water also function as aquatic eco-systems. Madhya Pradesh wetlands shelter many species of fauna and flora, of which the most widely explored, scientifically studied and appreciated are the aquatic reptiles and birds. Observation reveals that the increasing withdrawal of water from rivers for agriculture, industry and drinking water purposes and discharge of domestic and industrial waste has adversely affected the health of riverine eco-systems. Similarly, the urban water bodies are facing threats from encroachment and discharge of domestic waste. The authors further stated that much more has to be done to enhance our knowledge on status and trends of freshwater biodiversity. The authors applied economic valuation of costs and benefits of measures, aiming to conserve biodiversity.

It has been established that the presence of certain plants and animal species can be used as a barometer for assessing the health of the wetland. Bhatacharya et al. studied the status of East Kolkata Wetlands with special emphasis on water birds as indicator [31]. In this wetland, 14 aquatic, 12 semi-aquatic and 11 species of non-aquatic birds, 4 aquatic and 6 semi-aquatic species of reptiles, 6 species of amphibians, 40 species of fish, 11 species of prawns, 3 species of crabs, 20 species of molluscs and 26 species of insects were recorded. The focus is mainly laid on various species of water birds based in and around the East Kolkata wetland. The findings showed that pollution from human activities killed many species of birds and reduced the abundance of others. These changes in the abundance were used as an indicator to measure the state of the environment in the study area. The generated data also showed that the species richness of the site is lost as compared with the past.

Kulshreshtha et al. assessed the ecology and present status of flamingos at Sambhar Salt Lake, Rajasthan, India and tried to compare with the past records [32]. Massive ecological deterioration of this important flamingo habitat and a severe reduction in the populations of both species was witnessed in the 20th century and more recently during the current decade (2000–2010). The authors pointed that Sambhar Lake, a Ramsar Site, is currently facing a variety of threats – both climate-related and man-made. Hence they suggested adopting strategies for conservation management immediately to stop this fascinating wetland ecosystem from sliding into oblivion.

Dutta et al. estimated the avifaunal diversity of Bordoibam Beelmukh bird sanctuary, a nationally important IBA site of Northeast India. They recorded a total of

133 species of birds belonging to 41 families. Out of which 86 (64.7%), 23 (17.3%) and 24 (18%) species were resident, migratory and local mover [33].

Baruah et al. indicated that the wetlands of Assam have a fairly high production potential of fish [34]. However, the current regulations and system of management are not conducive to sustainable production from these water bodies. It is resulting in overexploitation and degradation. It is imperative that some form of co-management with local communities be established for the *beels* of Assam. Since 1977, a substantial number of *beels* have been handed over to the Assam Fisheries Development Corporation (AFDC) for maintenance. Under the present system of management, both the Revenue Department and AFDC lease out the *beels* for a period of five years at a time. The prime objective is to earn revenue for the State's exchequer. The system allows rich middlepersons to obtain the leases where the marketing of the fish is totally controlled by the lessee and to augment their benefits and income, the lessee catches the entire fish from the beel at a stretch. The provisions of the Indian Fisheries Act 1897, enacted for the protection and conservation of fish biota, are meaningless.

Deka et al. has used remote sensing for monitoring changes in spatial extent of freshwater lake Deepor Beel Ramsar Site, a major wetland of Assam [35]. The study revealed the potentiality of Landsat TM data for mapping the change in the wetland ecosystem. Considering on the sustainability of wetlands for delivering various functions such as flood storage, water quality continuation and providing habitat for various species of aquatic flora and fauna, an inventory of wetlands of any region is prerequisite for their conservation and management. Field observation shows that the ecosystem is facing both natural as well as anthropogenic threats. Rapid urbanization, Illegal settlements, industries, invasive species *(Eichhornia crassipes)* are the major cause of this wetland decline. It has been found that massive decline occurred between the period 1991 to 2001 i.e., 1.891 sq.km which was at the rate of -0.171 per year where as the decline between the period 2001 to 2010 was found to be 1.013 sq. km which was at a rate of -0.101. The total area of open water bodies has decreased by 2.904 sq. km from 1991 to 2010 i.e. 59.19%. Thus the overall rate of change in the water bodies from 1991 to 2010 to other land use categories was found to be -0.145. Hence the authors stated that the study will have high utility in preparing management plan for conservation of this ecosystem.

Conservation and wise use of wetlands has been given priority worldwide. India harbours diverse types of wetlands. Hence Panigrahy et al. highlighted the findings of the national-level inventory and assessment of wetlands carried out using RESOURCESAT-1 LISS-III data of 2006–07 at 1:50,000 scale [36]. The authors classified as Inland wetlands with 69.22% (10.564 m ha), whereas the coastal wetlands with 27.13% (4.14 m ha).They also observed significant variation in terms of water spread, turbidity of open water and aquatic vegetation during pre- and post-monsoon seasons.

Abbasi et al. studied on the application and capabilities of GIS in wetland management [37]. The study reported that GIS tool helps in producing the hidden patterns in a dataset, also to retrieve and edit data in the forms of cartography, graphs and tables and lastly to prepare intense maps in providing easy survey, spatial modeling and analysis.

Wetlands are highly variable and include oligotrophic as well as naturally eutrophic systems. Bressler et al. studied on the effects of nutrients on the physical, chemical and biological processes of wetlands [38]. Increase in the nutrients load may alter the biogeochemical processes, as well as the level of chemical may change in the water and soil which will have a cascading effect on the microbial, algal, plant, invertebrate and vertebrate communities. Most importantly it might reduce the effectiveness of wetlands as effective filters that protect downstream and ground water resources.

Raza et al. studied physical and chemical attributes as an indicator of soil and water quality of the grassland and wetlands of Makra Meadows (Elevation 3089 m) and Kallar Kahar (Elevation 554m), Pakistan [39]. The soil and the water samples exhibited wide differences among the grassland and the wetlands. The grassland ecosystem exhibited acidic soil and water, low electrical conductivity and lower nutrient concentration in soil and lower level of TDS unlike the Kallar Kahar.

J. Herrmann monitored a manmade storm water wetland that receives water from residential and road areas and examined the variation in water quality and the vegetation over the five years after inundation [40]. It was noticed that total nitrogen showed moderate or high concentration whereas total phosphorus levels were high to extremely high. The annual average reduction of nitrogen was 173 kg ha^{-1} y^{-1} that tends to increase over time, and for phosphorous was 12.1 kg ha^{-1} y^{-1}, which has the tendency to decrease. Vegetation was well established in the first year and after four years it has become denser. Benthic invertebrates were observed with 50 species of higher taxa in the first two years and gradually decreased the following years. The results were discussed in terms of wetland values for biodiversity and nutrient reduction, suggesting that these objectives seem possible to combine in storm water wetlands.

Deka et al. has studied the physico-chemical water quality properties and made a preliminary checklist of desmids flora of Urpad Beel (wetland) Goalpara [41]. The physico-chemical analysis of water showed that the dissolved oxygen values ranged from 3.9 to 7.26 mg/ l and BOD (Biological Oxygen Demand) fluctuated between 7.1to 13.8 mg/ l. During monsoon, surface runoff carries waste and sewage from the surrounding areas into the low-lying beds that eventually increase the respiratory activity of the heterotrophic organisms. The wetland is also stated to have direct impact due to encroachment and agricultural land use. The back flow of water from river Jinjiram to Urpod beel also induces heavy sedimentation. Further a total of 91 taxa were identified belonging to 14 genera namely *Closterium* (15.38%), *Euastrum* (13.18%), *Staurastrum* (7.69%), *Desmidium* (3.29%), *Actinotaenium* (3.29%), *Netrium* (2.19%), *Xanthidium* (2.19%), Hyalotheca (1.09%), *Micrasterias* (2.19%), *Staurodesmus* (1.09%), *Haplotaenium* (1.09%), *Spondylosum* (1.09%), *Bambusina* (1.09%) and *Cosmarium* and these are the most frequently encountered of all genera throughout the year making up forty one species (45.05%).

Bunn et al. highlighted the mechanisms and principles that link flow regime and the aquatic biodiversity and how altered flow changes can affect the biodiversity in fresh water habitat [42]. The aquatic biodiversity were found to be vulnerable to diurnal changes in flow and regulated river reaches below hydroelectric dams and the density and abundance of biodiversity depend on the velocity, depth and cover. Lastly, the authors concluded that association of the biodiversity and the habitat were influenced by flow variability at spatial scales.

Lee et al. adopted several new approaches to quantify wetland hydrologic characteristics and then describes and compares the hydrology, water quality, and ecology of ten isolated freshwater marsh and cypress wetlands in the mantled karst landscape of central Florida [43]. Comparisons indicated several hydrologic differences between the marsh and cypress wetlands in the study like the natural marshes had higher evaporation rates compared to cypress wetlands. Cypress wetlands remain nearly dry in a greater percentage of time than marshes. The water quality of natural marsh and cypress wetlands was similar, with a low pH, low conductivity, minimal alkalinity, and low concentrations of major ions. The hydrology and water quality of augmented wetlands differed substantially from natural wetlands, but ecological differences were less apparent. Hence the approaches used in the study can be applied to future studies and those results can be compared to this initial study population, allowing the comparative analyses to describe an increasing number of wetlands.

Haghighi et al. designed environmental flow release strategy to maintain the water availability of lakes and wetlands during seasons of high irrigation demand as construction of dams has led to an increase in water consumption for irrigation, eventually resulting in the dehydration of lakes and wetlands [44].

Miller et al. reported on their works undertaken in United Kingdom to develop a constant hydrological impact assessment approach on wetlands and indicated that even slight changes in hydrology may result in significant alteration of wetland processes, species composition and ecological functions [45]. This approach was based on fundamental hydrological principals and integrates four important concepts –

(1) building a sound conceptual understanding of the hydrological processes that control water movement into and out of the wetland and can be tested by a water balance;

(2) using a risk-based approach, which employs the simplest tool that is fit for the purpose of the study;

(3) recognising a hierarchy of tools from simple to complex that require different amounts of data, different user time and deliver different levels of confidence;

(4) although some sources of water for a wetland may be small, they may be critical at certain times, such as droughts, or in determining water quality.

This approach could manage to gain wide publicity in other countries as well.

Whigham et al. has worked on the water quality of the isolated wetlands. The water quality characteristics of the wetlands depend on the water source, substrate norms and the land uses associated with the wetland watershed [46]. As isolated wetlands have nutrient sink and they are connected hydrologically with other waters and wetlands, the loss of this phenomena would eventually have a negative impact on the downstream aquatic resources.

Carpenter et al. stated that increased nutrient concentration in the water causes decrease in aquatic oxygen level [47]. The dissolved oxygen is obviously decreased by the process of eutrophication due to algal death and decomposition.

S. Saha assessed water quality of four wetlands differing environmental constraints and a comparative study was done among them [48]. All the four wetlands showed special problems in compliance to their locations and natural and anthropogenic factors. The overall water quality index gave satisfactory to good level, however individual parametric analysis gave more accurate problems of the wetlands. The author further indicated understanding and quality assessment of the wetlands has become more important due to the change in the climate, hence extensive study of the wetlands is worth requirement.

Wang et al. investigated the influence of organic matter on the rate of K adsorption by selected soils (Ferric Ultisol, Orthic Ultisol and Vertisol) using a H_2O_2 treatment and a K ion-selective electrode technique [49]. The findings indicated that organic matter considerably promotes the initial fast rate of K adsorption and has more easily accessible adsorption sites for K compared with mineral constituents of the soils.

Guthambi et al. examined the difference of soil nutrients between improved and seminative pastures in plants and the soil quality characteristics in seasonally flooded wetlands [50]. The findings indicated total C, N and P were considerably higher in the shallow depth (0 – 15 cm) than the deeper layers (15 – 30 cm, 30 – 45 cm) for both improved and seminative pastures. Improved pastures were observed with greater amount of P in the higher layer than did the seminative pastures. According to the authors, plant and soil enrichment may be impacted by different land use practices which can lead to the alteration and function of the wetlands ecosystems.

Anderson et al. conducted a study to determine the differences in the development of soil between the planted and unplanted experimental marshes or between areas closer to the wetland inflow versus further away [51]. However in both the cases, no differences were detected in the transformation of soil nutrients.

Yellick et al. assessed whether the soil in different conditions of wetlands have altered in terms of element composition as the rationale was compared between good and poor conditions of wetlands [52]. As the wetlands with poor conditions can be typically disturbed by human and other anthropogenic interferences which can lower the diversity of native species and can eventually alter the element composition. It was indicated that organic matter content of the soils increased as quality of the wetlands tend to increase, and it was the most important variable explaining 40% of variation in the concentrations of elements.

Wang et al. studied on the accumulation and seasonal dynamic of the soil organic carbon in the wetlands of the yellow river estuary, China [53]. The findings regarding the temporal-spatial distribution and influential factors of soil organic carbon in four typical wetlands belonging to the Yellow River estuary showed that there was no significant difference in the contents of the surface soil TOC over the period among the four types of wetlands. The study also stated that it is essential to study the carbon pool and its variations for evaluating the carbon cycle process. There is an urgent need to assess and monitor the worldwide freshwater resources as the combination of rapid urbanization, industrialization, population growth, and low environmental awareness poses a major threat.

The concentration of soil is generally highly variable during a lake's seasonal cycle. A study was aimed by R. Quiros to study Nitrate and Ammonia mean concentration variation along the increase of the trophic state of lakes [54]. He indicated that the NO_3-N: NH_4-N ratio is directly related to the TN: TP ratio for lakes in general and shallow ones in particular.

The role of soil in natural wetland systems is the key in providing a number of ecology functions, such as the supply of wetland plant nutrients and the retention of nonpoint source pollutants. E.K.D. Stockman evaluated the physico chemical characteristics of the wetland soil for creation of mitigation wetlands to replace lost and/or damaged natural wetlands [55]. These physico-chemical properties influence the functions of supplying plant nutrients and retaining nonpoint source pollutants such as excessive nutrients and herbicides.

Murillo et al. studied wetland soils from a Mediterranean semiarid wetland (Las Tablas de Daimiel, Central Spain) to characterize the organic matter (OM) and determined its origin and transformation [56]. They observed that OM quantity and quality do not seem to depend on hydrology (although seasonal flooding is associated with less organic wetland soils) or soil characteristics. The authors further indicated that dominant vegetation and fire are the main drivers of OM content and composition.

Kujur et al. studied the variations in microbial biomass C (MB-C), N (MB-N) and P (MB-P) among seven different tropical soils (fresh mine, 6yr old mine, degraded wasteland, grassland, pesticide-treated, agricultural and forest soil) of Jharkhand, India were studied [57]. He observed that the clay percentage, water holding capacity, moisture, organic carbon, total nitrogen and available phosphorous were comparatively higher in forest soil.

Gupta et al. conducted a study to investigate the seasonal changes of the nutrients in the soil under different land uses i.e., natural forest, plantation and grassland of Jhilmil Jheel wetland, situated in Haridwar district of Uttrakhand, India [58]. He reported some interesting results of the chemical parameters responding to the seasonal meteorology. The higher values of soil pH was observed in summer season and the least in autumn season under different land uses i.e., higher in grassland followed by plantation and least was under natural forest. The soil organic carbon content was higher in winter season followed by spring, autumn and the least was observed in summer season under different land uses. The organic carbon content, Total Nitrogen and Available Phophorus were higher in the soils under natural forest followed by plantation and the least under grassland and observed higher in winter season and the least was observed in summer season.

Reed canary grass *(Phalaris arundinacea)* invasion is prevalent in wetlands and riparian fringes, and due to differences in vegetative growth and residue quality relative to native species, *P. arundinacea* invasion could result in measurable effect on soil organic carbon (SOC) pools and composition. To examine these questions Bills et al. studied the composition of soil organic carbon pools from areas invaded by *P. arundinacea* [59]. The authors noted a clear effect of *P. arundinacea* invasion on the cycling and composition of soil organic matter at the study site.

A. Sharpley studied about the fate and transportation of phosphorus in wetland soil and stated that the rate and extent of inorganic and organic P transformations in wetlands are modified by intermittent aerobic and anaerobic conditions, compared to the dry land soils [60]. Under aerobic conditions the solubility of P associated with amorphous Al and Fe compounds can be increased, but some P associated with crystalline Al and Fe oxides is desorbed only under extended waterlogged conditions. So, organic P mineralization may be enhanced by alternate soil wetting and drying cycles, changes in soil pH, and an increase in microbial activity.

B. Kerr studied the relationship between organic matter and nitrogen and reported that humus which is formed from raw organic matter by soil organisms is a valuable reservoir of nitrogen [61]. Humus has an anion exchange capacity and therefore can hold some nitrate, which reduces leaching from the soil.

In Ethiopia, wetland resources play a vital role in the lives of adjacent communities by helping them to achieve food security and livelihoods. Hence environmental factors determining the abundance and diversity of macroinvertebrate taxa in natural wetlands of Southwest Ethiopia was studied by Mereta et al. [62]. They have stated that lack of awareness and logistic constraints are important reasons for the weak consideration of wetland ecosystems by the country's development planners. Thus in this paper they have we set out to develop methods for predicting species–environment relationships. Decision tree models and Canonical Correspondence Analysis (CCA) were used to identify factors influencing macroinvertebrate community structure in natural wetlands of Southwest Ethiopia. It was found that *Corixidae, Baetidae* and *Hydrophilidae* had the highest predictive model performance. This indicates that these taxa have clear requirements regarding their environmental conditions. This was also further illustrated by the Canonical Correspondence Analysis (CCA) where the family of *Chironomidae*, common at nearly every sampling station in the wetlands, was plotted in the centre of the CCA axis. Vegetation cover, water depth, and conductivity were the most important variables determining the presence or absence of macroinvertebrate taxa.

Understanding the pattern and process related to biodiversity is a greatest challenge to the science of biological conservation. Hence an attempt has been done by Haileselasie et al. to assess the influence of water quality on the diversity and distribution of macroinvertebrates in Hiwane second order stream with primary objective to determine the ecological water quality status of Hiwane stream at different sampling sites using rapid field assessment screening methodology [63]. He indicated that species diversity is positively correlated with water quality and observed that man-made activities has lead to depletion of biota and any human activity in the drainage area may cause changes among physico-chemical parameter and this could lead to a severe impact on the benthic invertebrates of Hiwane stream river.

Tarr et al. examined the influence of hydro-period and concomitant changes in abiotic (wetland size, pH, conductivity, dissolved oxygen and water temperature) and biotic (predatory fish presence) characteristics on macroinvertebrate communities in isolated wetlands in southern New Hampshire [64]. The authors observed that aquatic invertebrate communities differed markedly with respect to wetland hydro-period, and in relation to the occurrence of predatory fish and hence suggested to retain a diversity of wetlands in the landscape to ensure the long-term persistence of aquatic invertebrate biodiversity.

Heatherly et al. has initiated a study on the Relationships between Water Quality, Habitat Quality, and Macroinvertebrate Assemblages in Illinois Streams [65]. They have sampled 53 streams throughout Illinois and examined relationships between macroinvertebrate community structure and numerous physicochemical parameters and the streams were clustered into four major groups based on taxa dissimilarity. Habitat quality and dissolved nutrients were responsible for separating the major groups in a non-metric multidimensional scaling ordination. Furthermore, the alignment of environmental factors in the ordination suggested there was a habitat quality–nutrient concentration gradient such that streams with high quality habitats usually had low concentrations of nutrients. Discrimination by community measures further validated the major stream groups and indicated that forested streams had generally higher biological integrity than agricultural streams, which in turn had greater integrity than urban streams. The results demonstrated that physical habitat degradation and nutrient pollution are important and these are often confounded determinants of biotic integrity in Illinois streams. In addition, the authors suggested that management of Midwestern streams could benefit from further implementation of multivariate data exploration and stream classification techniques.

Pena et al. observed the relationship between pH and benthic macroinvertebrates indices in Vermont streams [66]. Comparisons of the abundances showed that there were a relationship between the abundances and the ph (p=0.000964). Also the relationship between the *Hydropsychidae,* EPT and species richness and pH were made which showed a relationship of p=0.000109, p=0.00373 and p=8.35E-06 respectively.

Kashian et al. compared the macroinvertebrate fauna of a moderately impacted coastal wetland with the fauna of a nearby relatively pristine reference wetland [67]. The differences observed were, the impacted wetland had higher Cl, NH_4-N, NO_3-N, soluble reactive P, conductivity and lower dissolved oxygen level. Also fewer sensitive aquatic insects like *Ephemeroptera* and *Trichoptera* were observed.

Sarma et al. has studied on aquatic macroinvertebrates as bioindicator for assessing the health of wetlands, a case study in the Central Himalayas, India [68]. Their work was the first case study on the aquatic macroinvertebrates as bioindicators for assessing the health of Asan wetland (area 3.2 km^2), located in the foothills of Central Himalayas, India. A total of 32 species of macroinvertebrates were found with the *Ephemeroptera* and *Gastropoda* being the most abundant component of invertebrate's communities. Seasonal fluctuations in the density of macroinvertebrates revealed maximum density (451–503 indm_2) during winter and minimum (126–143 indm_2) during monsoon season. The density of macroinvertebrates was influenced by the anthropogenic disturbances and water level fluctuations causing disturbance in the littoral zone of the wetland. The statistical relationships between turbidity, transparency, dissolved oxygen and water temperature and macroinvertebrates of Asan wetland were also computed for assessing the impact of anthropogenic disturbances on macroinvertebrates.

Aquatic macro-invertebrates play significant role in responding to a variety of environmental conditions of rivers and streams and therefore may be used as bio-indicators for water quality assessment. Sharma et al. dealt with the population density and species diversity of aquatic macro invertebrate fauna to use it as a bioindicator for assessing the water quality of Kishanpura Lake, Indore [69]. The study showed the pond exhibit seasonal variation with regards to pollution level and it was also observed that an increase in the decaying matter enhances the growth of *Oligochaeta.*

Dahegaonkar et al. described the findings generated from the investigation of two lotic ecosystems namely river Zarpat and Wardah of Chandrapur, Maharashtra on benthic macroinvertebrates to estimate the impact of nutrient concentration from urban discharge [70]. The presence of species like *Chironomous larvae, Limnodrillus* and *Lymnia* indicated river Zarpat to be at stress, however the absence of less abundance of those in Wardah indicated as less pollutant aquatic ecosystem.

Anant J. Dhembare recorded distribution variables as frequency occurrence, relative density, relative frequency, relative abundance and important value among macroinvertebrates from Ashvi reservoir and indicated that these variables varied species to species [71]. The greater species diversity means larger food chain and more cases of inter-specific interactions and greater possibilities for negative feedback control which reduces oscillations and hence increases.

Sharma et al. studied on the macroinvertebrate assemblages as biological indicators of pollution in a Central Himalayan River, Tawi [72]. Significant relationships were recorded between physico-chemical parameters of water and the occurrence of specific genera and pointed out that significant change in macroinvertebrate assemblages were primarily due to changes in water quality.

However he claimed that the results generated is truly convincing to prove the macroinvertebrates as good indicators of water quality and should be used as bioindicators in long-term monitoring of this river.

G.A. Mieles studied on the relationship between aquatic biotic communities and water quality in a tropical river–wetland system (Ecuador) and indicated that nutrients, velocity and sediment as main drivers [73]. The authors further stated that higher densities of organisms were recorded in the wetland compared with the river.

Brazner et al. demonstrated an approach for evaluating the relative influence of geography, geomorphology and human disturbance on patterns of variation in biotic indicators derived from multiple assemblages for ecosystems that span broad spatial scales [74]. The authors observed that wetland vegetation, fish and bird indicators were the most, and macroinvertebrates the least, responsive to human disturbance. Hence they revealed that geographic (lake) rather than geomorphic factors (wetland type) had the greatest influence on the proportion of variance explained across all indicators, and that a significant portion of the variance was also related to response to human disturbance

B.K Sharma studied on the ecology, abundance, richness of zooplankton communities of Deepor Beel, a Ramsar Site [75]. He pointed out that richness and abundance are inversely correlated with water temperature and rainfall, and positively with specific conductivity and dissolved oxygen. Finally, zooplankton richness and abundance oscillated with annual frequency but during winter, it was observed to be quantitatively dominated by any individual species, and was characterized by higher species diversity with equitable abundance of various species.

Patra et al. stated that efforts have been made to ascertain the seasonal abundance and population dynamics of zooplankton community and its relationship with physico-chemical factors of the water bodies of Santragachi Jheel in the District Howrah, West Bengal [7]. The results indicated that zooplankton population differs significantly in relation to stations and seasons of the Jheel and population of Rotifera, the most dominant group was found to be positively influenced by water quality parameters in the Jheels. The authors further pointed that increment of population density of several zooplankton organisms (i.e., *Keratella tropica, Polyarthra vulgaris*) and low value of community indices especially species diversity and species richness indicated the rise of pollutional stress on the Santragachi Jheel.

M. Wills used National Sanitation Foundation Water Quality Index as one of the analytical tools in the cazenovia creek, NY, pilot watershed management project [76]. The WQI calculations were based on a relatively small, but spatially diverse number of samples that helped to summarise the voluminous data into one considerable value. However he further pointed out that disadvantage of the nonspecific WQI is that the impacts of individual analytes are ·smoothed out.

Gorgizade et al used NSF water quality index and Geographic Information System and prepared water quality zoning maps and evaluated the physical chemical, biological parameters and polluting agents in Bamdezh wetland [77]. The WQI reflected to be bad only in June whereas the rest of the seasons have medium quality. The spatial distribution or zoning maps of the wetlands indicated that if the wetlands in some part of the months are confined as a reservoir, the concentration of pollutants gets increased. Hence the author alleged that the combination of WQI and GIS can provide useful information for evaluation of water quality.

Behmanesh et al. assessed Water Quality Index of Babool Road River using Arithmetic Index method and National Sanitation Foundation method (NSF) [78]. He observed that in weighted arithmetic index method highest favorable value gives a low statistical value to the index whereas lowest favorable value gives a low statistical value to the index in NSF method. The results also revealed that although WQI of most of the stations are beyond acceptable limit but could be used for domestic and household purpose after purification.

Bhuyan et al. also assessed Water Quality Index in Subarnarekha River Basin in and around Jharkhand Area based on National Sanitation Foundation studies [79]. The findings highlighted the deterioration of water quality in the rivers due to industrialization and human activities and the parameter of greatest concern in the study appeared to be Faecal Coliform. The authors stated that it is due to the lack of the sanitary awareness among the inhabitants of the adjoining localities

Different biotic indexes have been proposed to study the composition, distribution, seasonal variation of benthic macroinvertebrates of the Nangal wetland by Brraich et al. for two years, from February 2013 to January 2015 [80]. The findings indicated that the wetland is moderately polluted that further affects the occurrence of benthic macroinvertebrates.

Troyer et al. used the oxygen Prati index and the ETHbios, which is a biotic index based on macroinvertebrates to assess the water quality of the riverine environment of a fast growing city in Southwest Ethiopia. They also assessed the chemical and ecological water quality of the streams and rivers for which they proposed possible remediation options that were evaluated with an empirical model [81]. They observed significant increase in oxygen consumption and in nutrient concentrations which indicate organic pollution originating from different diffuse and point sources of pollution. They also revealed the reduction of fecal coliform when the polluted river water passed through the Boye wetland, indicating the purification potential of the natural wetland and importance of conserving and protecting the same. Hence alleged, that waste stabilization ponds and constructed wetlands are highly promising techniques, as they provide a cheap, effective, reliable, and sustainable way to purify wastewater.

Roche et al. used BMWP and ASPT indexes for monitoring environmental quality in a neotropical stream for both dry and wet period [82]. He stated that to compare environmental quality between dry and wet seasons, use of the ASPT could be advantageous than BMWP.

Bascombe et al. formulated different indexes to study on macroinvertebrates as bioindicator and water quality management within urban catchments [83]. In the study the authors have identified ecological variations and indices related to hydrochemical and toxic peturbations which prevent the establishment of a stable ecosystem. The indices formulated are applied to the pollution condition and regime of the urban river to interpret in terms of water quality management.

Bhatt et al. proposed a new biotic index named Macroinvertebrate Water Quality Index to evaluate water quality in freshwater rivers [84]. The proposed index gave better result of the water quality of rivers compared to the others biotic indexes because it takes into account the abundance of taxa and reflects even the minor changes in abundance and community structure, it is flexible and gives freedom to select any sensitivity score system and it is universally applicable.

Seilheimer et al. compared Water Quality Indexes and Biotic Indexes like Wetland Fish Index (WFI), Wetland Zooplankton Index (WZI), and the Wetland Macrophyte Index (WMI) to evaluate the water quality of Laurentian great lakes [85]. The authors derived the Biotic Indexes to be less labour intensive, cost effective and have the potential to produce immediate results. However further suggested to use WFI and WMI as they produce comparable results, but WZI should not be used in minimally affected areas without broader studies.

Ompok pabo, an endangered fish is now restricted to only few natural habitat. Hence an attempt has been made by Sarma et al. to study the present status and habitat ecology of Ompok pabo (Ham-Buchanan) using the Shannon–Weiner diversity index (SWDI) in Goronga Beel, Morigaon, Assam [86]. SWDI was used to measure the diversity and abundance of fish population of the wetland and found in the range from 2.11 to 3.41, which significantly indicated maximum species richness of the wetland. Moreover, the floral and other faunal diversity of the wetland also showed important role in shaping microhabitat of the species.

Khalifa et al. used zooplankton as a biotic tool using different indexes viz: Species Richness Index (SRI), Wetland Zooplankton Index (WZI) and Saprobity Index (SI) to assess water quality of Lake Nasser, Egypt throughout different seasons in 2013 [87]. The study indicated WZI and SI to be somewhat reflecting good indication to assess water quality than the SRI which did not reflected the actual ecological status of the wetland.

Yadav et al. attempted to study ecological health of Chambal River using multiple indices viz. NSF Water Quality Index, Carlson Trophic State Index (CTSI) and Simpson Diversity Index (SDI) [88]. The results reflected overall ecological health in good range of 1- 2. Hence the water can be used for irrigation, bathing, aquaculture etc except for drinking purpose. The observed ecological health was also reported to be attracting large number of aquatic birds and animals.

Ibekwe et al. correlated microbial community composition and water quality changes within different cross sections of wetlands in compliance to the varying plant densities and composition in a free water surface (FWS) constructed wetland [89]. Shannon Weiner Diversity Index was used to generate microbial diversity and it was observed that microbial diversity was higher in the sections with 50% plant density than the 100%. Hence it concludes that wetlands with 50% plant cover may promote the growth of microbial density which accelerate the decomposition of chemical pollutants in a water body and improve the water quality of the same.

Hu et al carried out a study using tiny, unseen wetland creatures as crucial indicators of the ecosystems' health [90]. They found that a higher ratio of certain microbes, known as *Archaea*, to bacteria was a good sign of a healthy ecosystem

Jenyo et al examined the socio economic activities of man along the coastal wetland with a view to assess the resultant effect on the biodiversity of the area [91]. The study revealed that activities such as fishing using different fishing gears and chemicals, sand mining and agriculture directly exploit the wetland eventually leading to shore erosion, fish depletion, water pollution, extinction of some of the wetland dependent animals which will eventually cause decline in the productivity of the wetland.

Beels are the derelict or semi derelict wetlands, which are very much important fishery resource of Assam. Hence S. Baruah studied on the impact of beel fisheries on the socio economic life of the people of Lakhimpur district [92]. The ecological energy studies by the author showed that the wetlands have high level of productivity and the people depend on the beels for their daily consumption of fishes well as source of income for the rural folks.

Riba et al. attempted to analyse the changes and degradation that the Bordoibam Beelmukh Wetland has endured [93]. The study alleged that the wetland, a major part of which is a bird sanctuary was formed due to shifting of meandering courses of river Champora. Presently, twenty Four species of Birds have been witnessed in the study area and amphibians and reptiles, like *Hoplobatrachus tigerinus, Bufo melanostictus, Rhacophorus spp*. Fishing Cat (*Prionailurus viverrina)*, and Hog deer (*Axis Porcinus)* have also been recorded. The wetland is reported to be fragile and disturbed by human. Encroachment due to increase of population, earth filling, bank erosion due to tiling of soil and lastly poaching of water birds when migratory birds visit during winter are some of the problems indicated by the authors.

M.J. Bhuyan attempted to study on the impacts of Hahila Beel, Nagaon on the socio economic lives of the locals [94]. The study reported distinct economic and social values on the life of the locals from which they generate some indigenous source of income from the wetland. The beel has manifold uses like fishing which is permanent, seasonal sources of income included root collecting (especially of arum), grass cutting for commercial purposes, income generated from banana trees, firewood collection, income from lotus and its body parts, irrigation, etc. However the beel asked for a better management approach and participation and lastly the involvement of local community has been proposed for its long term sustenance.

Sarma et al. has studied on the utilisation of wetland resources by the rural people of Nagaon District, Assam [95]. They have observed that man’s dependence and association with wetland is an important aspect as people get benefitted by using its resources. The study has been conducted to assess the economic benefits derived from the wetland resources by the rural people of the district and also to assess their socio-religious and cultural attachment with the wetlands. Also reported, this resourceful wetland has been found to be degrading due to some anthropogenic activities.

Mohanty et al. under the Ansupa Lake development Project, adopted for community mobilization and asked the locals to participate in implementing the sustainable conservation of the Ansupa Lake, a famous lake of Orissa [96]. They undertook a detailed socio-economic and socio-cultural study through RRA and PRA techniques. These data were used by the state government in the integrated management plan and different Self Help Groups have been formed. Awareness programmes, impartment of trainings for alternate income generation activities, active participation of the locals have been initiated and hence the locals were reported to be actively participating in the conservation of the wetland.

Long regarded as wastelands, wetlands are now recognized as important features in the landscape that provide numerous beneficial services for people and for fish and wildlife. The value of a wetland is an estimate of the importance or worth of one or more of its functions to society. For example, a value can be determined by the revenue generated from the sale of fish that depend on the wetland, by the tourist dollars associated with the wetland, or by public support for protecting fish and wildlife.

-oOo-