Chapter-2

REVIEW OF LITERATURE

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2.1 Limnology

Limnology, as a distinct field of Science, has existed for less than 40 years. The limnochemical characteristics of the water quality include physical and chemical parameters. The main purpose of analyzing physical and chemical parameter of water is to determine its nutrient status. Since, the water contains dissolved and suspended materials in various proportions, its physical and chemical characteristics differ along with its biological characteristics. It is not possible to understand biological phenomena fully without the knowledge of water chemistry as the limnobiological and limnochemical components of the ecosystem are interacting with each other.

The limnological studies have attracted attention in India in recent years. Adoni (1975) studied the Sagar Lake for microbes and discussed the factors influencing their existence. Rai and Hill (1980) made an extensive study on physical and chemical and microbiological parameters of central Amazon lakes and classified them into oligotrophic and eutrophic water bodies based on the bacterial density, electrical conductivity, p^H, DO (Dissolved oxygen), silicates and phosphates. Imhoff *et al.* (1980) studied the physical and chemical and biological parameters of eutrophic desert lakes of Egypt and pointed out that sulphate, carbonated, chlorides, sodium and other traces like magnesium, calcium and potassium play a significant role in the distribution of algae and bacteria.

The other noteworthy publications that appeared with respect to India limnology include Pandey *et al.* (1980) on the nutrients in Chilka lake; Zutshi *et al*. (1980) on the limnological aspects of nine lakes of Jammu and Kashmir; Purohit and Singh (1981) on the physical and chemical aspects of Nainital lake and Mir and Kachroo (1981) on the limnology of Kashmir lakes. Beaver *et al*. (1981) found that the water temperature influence the productivity pattern in the lakes of Florida.

Kumar and Sharma (1991) studied the Pichhola Lake and reported that the electric conductance, p^H, total alkalinity and nitrates at higher concentrations increase the productivity status of the lake and these parameters could serve as indicators in assessing the tropic level of the water bodies. Molot and Dillon (1991) discussed the nitrogen and phosphorus ratio and chlorophyll production in the lakes of Central Ontario.

Borker *et al*. (1992) from Goa studied the diurnal variations in physical and chemical factors of a lake near Marmugoa, Goa and concluded that dissolved oxygen (DO), Free CO_2, p^H, chloride and total alkalinity in higher concentrations could accelerate the lake to become highly polluted. Nayak (1993) investigated Mathyatal Lake and recorded the physical and chemical characteristics and associated biological components and noted that the temperature and CO_2 are negatively correlated with each other while inverse relationship is noted between water transparency and bicarbonate content. Recently, limnological studies on high mountain lakes were reported by Larson *et al*. (1995) in Washington State, USA. Olila *et al*. (1995) studied the distribution of inorganic phosphates in the sediments of two shallow eutrophic lakes of Florida. Hosetti *et al*. (1995) have studied the limnology of a eutrophic pond with reference to physico-chemical factors at Navile, Shimoga.

The succeeding contribution to the field of fresh water bodies with reference to the distribution of phytoplankton and water chemistry has been recorded in the publication of Frenette *et al*. (1996) on the size dependent changed in phytoplankton, carbon and nitrogen uptake in the dynamic mixed layer of Lake Biwa. Arivazhagan and Kamalaveni (1997) discussed the seasonal variations in physical and chemical parameters like DO, chloride salinity and planktonic composition of Kurichi pond. Baruah and Barthakur (1998) work on the water quality of ponds and assessed the purity of potable water in Chandrapur area of Kamrup district, Assam. Swarnalatha and Narasingarao (1998) have studied the ecology of Banjara Lake with reference to water pollution by domestic wastes and highlighted the status of eutrophication of this water body.

Ahmed *et al*. (1999) observed the physical and chemical factors of Kaptai Lake, Bangladesh. They pointed out that Air temperature was always higher than water temperature. Vertical variation in temperature (0.8- 4.7°C).The lake was found to be slightly hard and alkaline (p^H), DO (6.4-9.1 mg/1) and Free CO_2 (4.0-6.0 mgll) contents showed favourable condition for aquatic lives. DO at different depth show no wide variation (1.0- 2.4 mg/l). Conductivity ranged between 91.9 ± 7.1 and 106.4 ± 5.2 ms/ cm. Singh and Jha (2000) worked on monthly variation in physical and chemical properties of sediments of Karwar Lake of North Bihar, India.

The investigations on surface water bodies that appeared during 2008 include those of Pejaver and Gurav (2008) on the water quality of Jail and Kalwa Lake, Thane, Maharashtra. The Jail Lake is found to be relatively more organically polluted and greater degree of eutrophication than the Kalwa Lake. Among water quality parameters, a positive correlation was found between chlorophyll and temperature, suspended solids, p^H, DO (not with chlorophyll C). A negative correlation was seen between chlorophyll and light penetration. The chlorophyll a and b showed negative correlation with CO_2, silicates and phosphates. A large number of investigators such as Puri *et al*. (2011) have investigated the water quality index (WQI) of lakes in Nagpur City, Maharashtra (India). The calculation (WQI) for various studied lakes showed fair water quality in monsoon season which then changed to medium in winter and poor for summer season. Gorewada Lake showed medium water quality rating in all season except monsoon season. Futala, Ambazari and Gandhisagar Lake have also declined in aesthetic quality over past decade.

Chandra *et al.* (2012) have described the water quality of various lakes i.e. Porur lake Chennai, Hussan Sagar, Hyderabad, Vihar lake Mumbai in India. Water samples were collected from six different sites and composite sample prepared were analyzed. Water pollution indicates that these parameters were manifold higher than the prescribed limit by the WHO & BIS standard. Pradhan *et al*. (2012) stated the water quality of Chilika Lake. It was observed that all the parameters were above permissible limit except at the sample site $S_{2.}$ Islam *et al*. (2012) observed the hydrological properties and water quality characteristics of Chini

Lake in Pahang, Malaysia. Based on the Malaysian water quality Index (WQI), the water in the Chini lakes was classified under class II, meaning it is suitable for recreational activities and safe for body contact. Khan *et al*. (2012) have investigated the water quality of Triveni Lake, physical and chemical parameters were studied. The result revealed that there were significant seasonal variation in some physico-chemical parameters and most of the parameters were in normal range and indicated better quality of lake water.

Further, investigation on the physical and chemical characteristics of freshwater bodies include those of Yadav *et al*. (2013) on physical and chemical characteristics of Mahil Pond in Jalaun district of U.P. India. Different parameters were studied viz., Rain fall, Humidity, DO, BOD, Alkalinity etc. The results indicated that water of the pond lies just below the level of eutrophication. Sushil *et al*. (2014) on limnological characteristics of Anchar lake, Kashmir and concluded that positive correlation among all the physical and chemical parameters except DO. Choudhary *et al*. (2014) described the seasonal variations in some important physical and chemical parameters and biological analyses of the three pond of Sasaram, Bihar. The data collected in various seasons revealed that those analyzed parameters were within permissible limit for fish culture. BOD of the ponds falls under moderately polluted category which should be solved in future for better productivity. Laishram and Dey (2014) studied the water quality status of Loktak Lake, Manipur. A total of eleven parameters were monitored during a period of one year. Mean values of the physical and chemical parameters like DO and BOD studied were found higher than the world Health organization (WHO) guidelines.

A few more publication related to the study of lentic water bodies include those of Barman *et al*. (2015) studied the seasonal variation of physical and chemical parameters of lakes in West Garo Hills of Meghalaya state in India. Bora and Biswas (2015) worked on water quality and Ichthyofaunal diversity of Moridikhow (an Oxbow lake) in Sivasagar district of Assam. Air temperature, water temperature, p^H, DO, Free CO_2 and alkalinity were studied to know the aquatic health of the lake.

Singh and Jayakumar (2016) studied the water quality of Kanwar lake (largest natural oxbow lake in the Indian subcontinent), Bihar, India. The results were compared with surface water quality standard given by Bureau of Indian standards (BIS). The values of all parameters were found in the range of prescribed limits, except DO. All the parameters exceeded the previously published values, which clearly indicated about enhanced level of pollution. Deepa *et al.* (2016) studied the seasonal variations of physical and chemical parameters of Koratur Lake of Tamil Nadu and highlighted the various parameters of lake. The lake was found to be moderately polluted and suffered from eutrophication.

Recent investigations on the water quality of lentic water bodies include those of Saha *et al.* (2017) on the three different pond water of Naida district of West Bengal. The finding established that the well managed pond (P-2) showed better ecological conditions compare to unmanaged ponds. Dar *et al.* (2017) studied the water quality of Dal lake of Jammu & Kashmir. Due to the higher values of BOD, COD it results in the less amount of DO present in the lake water which causes the direct threat to lake Ecosystem. Heavy metals such as Pb, Cr. Fe, Hg etc are of special concern because they produce water or chronic poisoning in aquatic animals. Chakraborty *et al.* (2017) discussed the water quality of Diplai beel, Haloidol beel, Gour beel and Gaurang river wetlands of Assam. The water parameters of the beels revealed that all the water samples from different habitant were safe for drinking, batting as well as other domestic uses. Rashmi *et al.* (2017) stated the water quality of Shanti Sagara Lake of Karnataka, India. Shanti Sagara Lake is the second largest lake in the Asia. Physical and chemical characteristic like Hardness, BOD, DO, TDS, chloride are within the limits in the lake water and alkalinity, acidity, total solids, TSS are exceed the limit in the lake water. The WQI values show the lake water is soft and it is very fit for the domestic uses.

Similar types of contributions have been made by a number of other workers include those of Kalita *et al*. (2018) on Deepor beel (natural wetland) of Assam. The 13 physical and chemical water quality indicators used. The WQI value for these samples ranges from 78.82 to 158.25. The highest WQI value of 158.25 was recorded from site- 2 (Pamohi near railway bridge) which is a picnic spot and its water is unsuitable for drinking and other house hold purposes. Tamuli *et al*. (2018) studied on physical and chemical characteristics of Morakolong beel (47 No.) of Morigaon district of Assam, India and found that the water of the beel is productive.

2.2 Fish Diversity

The fish is the most important aquatic community that is of concern to man. They live in almost all conceivable aquatic habitats. Fishes are most diverse among vertebrates but have not been well studied (Bone and Marshall, 1983; De Silva *et al*. 2007). Currently, the global fish diversity has been estimated to be about 28,900, which could increase to 32,500 when the world's lchthyofauna has been completely inventoried (Nelson, 2006). About 12,740 species of freshwater fishes belonging to 207 families and 2, 513 genera have been recorded (www. fishbase. org; Leveque *et al*. 2008). Among 2,500 species of fishes found in India around 930 are freshwater species and the rest 1,570 are marine species (Kar, 2003).

The distribution pattern of freshwater fishes varies globally. The Neotropical region is richest in fish diversity with over 4,035 species in 705 genera and where as Australia has the lowest fish diversity with about 261 species in 94 genera (Berra, 2001).

Table 2: Biogeographicl distribution of freshwater fishes (www. fish base. org; Leveque *et al.* 2008).

Biogeographic realm	Number of species	Genera
Neotropical	4035	705
Afrotropical	2938	309
Oriental	2345	404
Palaearctic	1844	380
Nearctic	1411	298
Australia	261	94

Each continent has a distinctive fresh water fish fauna (Berra, 2001), but most of the species belong to five taxa: the *Siluriformes*, the *Cypriniformes*, the *Charciformes,* the *Perciformes* and the *Cyprinodontiformes* (Leveque *et al.* 2008). Among primary freshwater groups, the *Siluriformes* are by far the most widespread and are found in North and South America, Africa, Europe and Asia. Whereas the *Perciformes* and the *Cyprinodontiformes* belonging to the secondary freshwater fishes are the most wide spread and occur in North and South America, Africa, Europe and Asia (Briggs, 2005; Leveque *et al*. 2008).

According to Kottelat and Whitten (1996) the East, South and Southeast Asian Countries have about 7447 species equivalent to 35-40% of the world's freshwater Ichthyofauna. Individual Asian countries have rich diversity of freshwater fish Viz., China (1287 species), Indonesia (1037 species), India (724 species), Thailand (661), Malaysia (527) etc., (De Silva *et al.* 2007)

The review of literature indicates that a comprehensive account of Indian fishes was worked out by Francis Day in (1878, 1889) for the first time. In the past and present centuries a number of researchers and taxonomist added a valuable contribution on fish diversity and taxonomy. A few of them were Hamilton (1822) prepared an account on the abundance of fish fauna in river Ganges. Shaw and Shebbears (1937) documented on fishes found in Northern Bengal. Hora (1921) presented a view on the fish and fisheries in Manipur. Dey (1973) provided more information by working on the taxonomy and distribution of Ichthyofauna in Hill Streams located in different regions of Northeast India. Sen 1982 and 1985) studied the ecology and systematic distribution of Ichthyofauna in Assam and its neighbouring states. Jayaram (1981) did a massive study on freshwater fishes in Burma Pakistan, Sri Lanka, Bangladesh and India.

Menon, (1999) prepared a checklist of freshwater fishes in India.Talwar and Jhingran (1991) investigated and documented on Inland fishes of India and its adjacent countries.

Nath and Dey (2000) reported on the fish fauna and fisheries of northeast India. Dey and Kar (1990) documented about the trends in fish yield in Sone Lake of Assam. Kar and Dey (2000) reported the yield trend and conservation status of major carps in Lake Sone of Assam. Kar and Barbhuiya (2000) studied the Ichthyo fauna diversity of Chatla Haor in Assam. Kar (2006) documented the fish fauna of river Barak in Tripura and Mizoram and Vishwanath *et al*. (2007) prepared a list of fishes of North East India. Nelson (2006) estimated 27, 977 aquatic living species in the world. India has 2,118 fish species distributed in different ecosystems (Kapoor *et al*. 2002).

In India, the major hot spots of freshwater fish biodiversity are the Western Ghats and North- east India (Kottelat and Whitten, 1996). Day (1878, 1889) from British India described 1418 fish species belonging to 342 genera. Jayaram (1981) from Indian also listed 742 species of freshwater fishes under 233 genera that belonged to 64 families and 16 orders. Talwar and Jhingram (1991) estimated 930 species of freshwater fish belonging to 326 genera and 99 families. Freshwater bodies of Manipur state also have rich fish diversity (Vishwanath *et al*. 1998).

Jayaram (1999) listed 852 freshwater species of fishes under 272 genera, 71 families and 16 orders, including both primary and secondary freshwater fishes from India, Bangladesh, Myanmar, Nepal, Pakistan and Sri Lanka. The checklist of Menon (1999) listed 446 Primary freshwater species under 33 families and 11 orders from Indian region alone. On a global scale, Indian fish populations represent 11% of species, 24% of genera and 57% of families (NBSAP India, 2005). 1042 species of freshwater fishes belonging to 71 families are reported from the Indian continent (Jayaram, 2010).

Floodplain wetlands and oxbow lakes are highly productive aquatic ecosystems and provide breeding and nursery ground for a number of aquatic organisms including commercially important fishes. The average fish yield rate from these Beels has been estimated at 172.9 Kg. ha^{-1} yr^{-1} (Shrivastava and Bhattacharyya, 2003), which is much higher than that from other lacustrine open water bodies of the country. Beels are considered as one of the most potential inland fisheries resource of India in general and Assam in particular because of their high fish production potential (1000 –1500 Kg ha^{-1} yr^{-1}) (Sugunan *et al*. 2000) and considerable resource size.

The information on diversity of different biotic communities of floodplain lakes of the country is scanty and Scattered except some reports of Chacko (1948) listed 33 fish species from the Periyar Lake, Tamil Nadu. Khan (1987) from Kashmir, Rai and Dutta Munshi (1988) from Bihar recently, a comprehensive account on the fish biodiversity in freshwater perennial water bodies in East Midnapur District of West Bengal has been given by Bhakta and Bandyopadhyay (2008).

Zacharies *et al*. (1996) reported 35 fish species, 21 genera and 11 families from Periyar Lake. Arun (1997) listed 27 species from Periyar lake stream system. Kar *et al*. (2006) studied diversity and the effect of environmental variable on fish of Sone Lake in Assam. A total 54 fish species belonging to six orders and 19 families were recorded from the Periyar Tiger Reserve, Kerala, India by Radhakrishnan and Kurup (2010). Seethal *et al*. (2013) listed 22 fish species belonging to 10 orders and 17 families from Ashtamudi Lake, Kerala.

Further, 42 icthyofaunal species that belonged to 32 genera, 15 families and to 6 orders from Utra Lake in Manipur were reported by Devi *et al.*(2014). Wani (2015) recorded 21 species, 6 orders II families and 17 genera from the Sagar Lake, Madhya Pradesh. Lakshmi *et al*. (2015) listed 78 fish species belong to 14 orders, 37 families and 57 generas were identified from Kolluru Lake. Maibam *et al.* (2015) reported 48 different speices of fishes under 5 orders, 17 families and 33 genera from Loktak Lake, Manipur. Borah *et al.* (2017) listed 50 nos of indigenous fish species along with one species of exotic fish species from Kankati beel of Biswanath District of Assam, India.

Recently, Nayaka (2018) reported 10 species under 3 order and 5 families from Mallasandra Lake of Karnataka. Nayaka (2018), total 08 species of fishes belonging to 07 genera and 02 orders were identified from the Bugudanahalli Lake, Karnataka. Chakraborty (2018) listed 177 species of fish, belonging to 31 families from the Northern West Bengal, India. Shivaraju *et al.* (2018) confirmed the presence of 10 species of fishes that belonged to nine generas, three families and two orders from the Durgadahalli Lake, Karnataka.

2.2.1 Fish Diversity of North-East India

North-East India has been considered a hotspot of fresh water fishes.The rich diversity of North-East India is assigned to the notable geomorphology of this zone (Kar, 2005). It also has rich freshwater system like river, streams, tanks, lakes (locally called as Beel) and reservoir. Starting from the pioneering works of Himilton (1822) followed by Day (1878), a number of fish species was reported from the region.

Hamilton (1808-1814) made a detailed survey of fish fauna of eastern provinces including Assam. Beaven (1877) published the "Handbook of freshwater fishes of India" which contains a short description of about 417 freshwater fish species out of which 46 species are reported from Assam. Hora (1941) made remarkable contribution to the Ichthyology of the region till the middle of 20^{th} century.

A large number of fishes ranging between 172 to 267 from north-east India have been reported (Ghosh and Lipton, 1982) (Sen, 2000). Sarkar and Ponniah (2000) tabulated 297 speciess that have the potential as food, sports and aquarium fish. The 297 species belonged to 74 generas and 27 families. The National Bureau of Fish Genetic Resources (NBFGR, ICAR), Lucknow in 1992 identified nine endemic fish species in North-Eastern region of India as most threatened. Bhowmik and Ayyappan (2000) estimated that so far about 172 fish species have been listed from North-Eastern region of India of which 33 representatives were endemic in their distribution to this region.

Assam, the second highest province of NE India, is a global hotspot for high faunal diversity. Here, until then around 185 species that belonged to 98 genera and 34 families have been listed (Bhattacharyya *et al*. 2000). Similar types of contributions have been made by a number of other workers in the field of fish diversity of Assam and include those of Dey (1981) monitored hydrobiological changes in important commercial lakes of Kamrup district in Assam and their influences on the production of fish. Kalita *et al*. (2000) studied the potential of fishery in river Sonai of Morigaon district, Assam. Biswas and Boruah (2002) studied the problems and related prospects for developing the fisheries in river Brahmaputra basin. Kar (2003) wrote on fishes from Barak drainage, Tripura and

Mizoram. Kar (2005) studied the conservation status of fishes in river Barak of Mizoram and Tripura. Biswas and Choudhury (2008) studied the ecology of Ichthyofaunal diversity in wetlands of upper part of Assam and Bhuyan *et al.* (2009) observed hydrobiology and the status of fisheries in Sondoba Beel of Morigaon in Assam.

Further, study on the fish diversity of Beels (wetlands) in Assam include those of Sand *et al.* (2012) on Eco-hydrobiology of Urpod wetland of Goalpara, Assam, who reported a total of 60 fish species belonging to 21 family. Kashyap *et al*. (2012) studied on the fish diversity of floodplain wetlands of central Brahmaputra valley zone of Assam, a total of 53 fish species under 35 genera, 21 families and 8 orders were documented. Barbaruah *et al*. (2012) listed 36 species; *cypriniformis* were the dominant group from Monohal Beel, Morigaon, Assam. Sarmah *et al*. (2012) recorded 77 species from Goronga Beel, Morigaon, Assam. Chakravarty *et al.* (2012) recorded 75 fish species belonging to 6 orders from Kapla Beel, Barpeta, Assam. Goswami and Kalita (2012) recorded 54 species from Deepor Beel, Assam. Further, Deka and Dutta (2013) studied Ichthyo-faunal diversity and status in Barbila Beel, Nalbari, 44 species belonging to 14 families recorded.

A few more publications related to the study on Limnology and Ichthyology includes those of Barbhuiya *et al*. (2015) on Dhir Beel at Dhubri district of Assam, 71 species were recorded. Bora and Biswas (2015) listed 40 fish species, 13 families from the Moridikhow (Oxbow lake) from Sivasagar. Bordoloi and Hazarika (2015) studied biodiversity and conservation status of Doria Beel, Majuli and reported 55 species, 7 order and 19 families.

Rahman *et al*. (2016) studied the comparative study on Ichthyofaunal resource of Charan and Manaha beel of Morigaon district of Assam and 65 species, 5 exotic species, 43 genera, 21 families, 7 order is recorded. Chhetry and Deka (2016) listed 47 species, 4 exotic fish species, 33 genera, 18 families, 6 orders is recorded from *era* Kopili Beelof Karbi anglong district. Kalita *et al*. (2016) recoreded 48 species, 5 exotic species, 35 genera 18 families, 7 orders from Motapung Maguri Beel (wetland) of Tinsukia district.

The study on Ichthyofaunal diversity of Beels (wetlands) that appeared during 2017 include those of Nag *et al.* (2017) listed 72 fish species including 4 exotic species belonging to 53 genera, 25 families, 8 orders from Dhir Beel, Dhubri District, Assam. Sinha *et al*. (2017) recorded 67 species, 4 exotic species, 49 genera, 25 families, 8 orders from Diplai Beel, Kokrajhar. Borah *et al.* (2017) listed 50 species, 01 exotic species from Kankati Beel of Biswanath District, Assam, India.

2.3 Macrophyte Diversity

Aquatic macrophytes are referred to as water plants, as well as amphiphytes and/or amphibian plants. These consist of mainly aquatic and wetland vascular plant species belonging to Pteridophytes and Angiosperms and exclude filamentous algae and grow as a natural biotic component in most shallow, still slowly running water bodied and wetlands. In general, these represent plants which are found in around the water bodies (Das, 2013).

The aquatic macrophyte is the important source of food, fodder, herbal medicine and domestic household materials. Macrophytes, as a component of fresh water ecosystems plant an important role in the structure and functioning of the aquatic ecosystems (Pandit, 1984; Wetzel, 2001)

During the last few decades several works relating to aquatic flora have been carried out by many workers throughout the world including various parts of India. Unni (1971) observed the vegetations of river banks, ponds and swamps in Rajpur. The biomass, distribution and seasonality of aquatic macrophyte of Lake Opnicon were studied by Crowder *et al*. (1977). Billore and Vyas (1981) also observed the distribution and production of aquatic macrophyte in Pichhola Lake of Udaipur. Kodarkar (1996) examined the conservation status of five Lakes in the vicinity of Hyderabad in Andhra Pradesh. Salasker (1998) evaluated the environmental aspects of the Powai Lake. Dey and Kar (1989a) documented on aquatic macrophyte species found in Lake Sone of Assam. Similarly Kar and Barbhuiya (2000) studied on aquatic macrophyte found in Chatla Haor which is a flood-plain wetland located in Cachar district of Assam. Bhaumik *et al*. (2004) observed macrophyte and its associated fauna of flood plain wetland ecosystem in West

Bengal. Kumar and Pandit (2005) studied the community architecture of macrophyte species found in Hokarsar wetland of Kashmir. Ghavzan *et al*. (2006) evaluated the effects of different environmental factors on the ecology and distribution of macrophyte species. Devi and Sharma (2007) studied the diversity of aquatic macrophyte in Awangsoipal Lake of Manipur.

Studies on aquatic and marshland plants of India are well documented by many authors including Biswas and Calder (1937), Mirashi (1954), Patnaik and Patnaik (1956), Sen and Chatterjee (1959), Maheshwari (1960), Chavan and Sabins (1961), Subramanyam (1962), Majumdar (1965), Vyas (1964), Unni (1967), Bhaskar and Razi (1973), Kachroo (1984), Lavania *et al*. (1990), Bhowmik *et al.* (2008), Chowdhury (2009), Chowdhury and Das (2010, 2011).

Further, several workers have conducted macrophytes survey in lakes/wetland from different parts of India viz, Alwar lake, Alwar Rajasthan, Sagar lake, Sagar Madhya Pradesh. Sharma and Singhal (1988) recorded 11 species of macrophytes from a trophical lake Sarrornagar lake, Hyderabad, Andhra Pradesh. Kodarkar (1996), Meshram and Dhande (2000) also studied aquatic macrophytes in lake Wadali of Amravati and affirmed that macrophytes can stimulate growth of phytoplanktons and also can help in recycling the organic matter. 25 species of macrophytes were recorded by Ambasht (2005) from Gujarat in Tal of Jaunpur Township in North India. Aquatic macrophytes of Husain Sagar Karanataka were studied by Narayana *et al*. (2005). Kiran *et al*. (2006) recorded 15 species of macrophytes the fish culture ponds at Bhadra Fish farm, Karnataka. Game and Salaskar (2007) recorded the macrophytes on Malchmali Lake, Thane, Maharastra. Dhore and Luchare (2014) recorded 15 species of mactrophytes in Yavatmal district. Bhute and Harney (2017) listed macrophytic diversity of Nagrala lak e of Bhadrawati Chandrapus (M.S.) India, a total 15 species belonging to 5 groups and 14 families were recorded.

A few researchers in Assam have documented on the wetlands and aquatic plants of the state (Malakar, 1995; Verma, 1971; Kar, 2000). Ecological studies on aquatic macrophytes of Assam were also carried out by few researchers (Baruah *et al*. 1997; Dutta, 2005; Deka and Sarma (2014).

Many terrestrial weeds are also found in the ecotone region of wetlands that possess several medicinal properties. The study of such weeds having medicinal properties from the crop fields have already been reported (Bhattacharyya and Borah, 2008), many of which grow in the ecotone region of wetlands of Nalbari district of Assam as well. Studies on medicinal plants which also grow in the same ecotone region and are used by Bodo tribe of Nalbari district of Assam and ethno medicinal uses of plants species which also grow well in the ecotone region of wetlands and terrestrial habitats used by the Sarania tribe of Nalbari district of Assam have already been reported by earlier workers (Bhattacharjee *et al.* 2001; Bhattacharjee *et al*. 2002; Bhattacharjee *et al*. 2006).

The study on herbal medicines obtained from the plant species growing in the marshy habitates of wetlands are used by the common people in Barpeta district of Assam was also carried out by the earlier worker (Bhattacharjee *et al*. 2008). Das (2013) recorded 128 macrophyte species belonging to 100 genera and 50 families from the Kamrup district of Assam. Dutta *et al*. (2014) reported a total of 68 plant species that belonged to 28 families and 49 genuses from Kapla Beel in Barpeta district of Assam. Deka and Sarma (2014) recorded 137 species 114 genera and 53 families from the aquatic bodies of Nalbari district in Assam. Sarma and Borah (2014) listed 228 plant species, 153 genera and 57 families from the five wetlands of Sonitpur district of Assam. A few works have also focussed on floristic diversity of aquatic ecosystems of Assam (Baruah, 2003; Gogoi, 2006; Kalita, 2008; Sarma and Saikia; 2010, Baruah *et al.* 2011; Dutta *et al.* 2011and Sarma and Deka, 2014)

2.4 Aquatic Plant and Elements

Aquatic plants are normally found growing in association with free standing water level at or above the surface of the soil. In some instances, the plants may merely be growing near the water. They are conspicuous plants dominating diverse natural and man-made wetland from small ditches, ponds, irrigation canals, sewage lagoons, streams, rivers, water reservoirs, shallow lakes and marshes to swamps (Mutr Harah *et al.* 2005). These diverse plants groups can be separated into four categories based on their habit of growth: floating unattached, floating attached, submersed and emergent (Pancho and Soerjani, 1978).

The body of all living organisms is made up of cells. Each cell is formed by some non-living inorganic as well as organic molecules. The inorganic biomolecules include water; minerals etc. up till now 36 elements have been discovered from different cells of which 12 elements have been found to occur in every cell. Inorganic biomolecules present in the cell are of three main types- Minerals, Water and Gases. Minerals have been classified into three major categories on the basis of their relative concentration- Major elements, trace elements and Ultra trace elements. Organic molecules are Carbohydrates, lipid, Proteins, nucleic acids, vitamins, hormones etc.

Major elements are oxygen, carbon, hydrogen and nitrogen. The major elements have great biological significance as they combine to form the macrobiomolecules (carbohydrates, proteins, lipids etc.) of the cell. Trace elements occur in low concentration in the living cell. The trace elements (calcium, Phosphorus, potassium, sodium, magnesium, iron etc.) play important role in cellular activities. Ultra trace elements are relatively very low in the protoplasm of the cell. The ultra trace elements include copper, cobalt, molybdenum, manganese, zinc etc.

Mineral salts are essential for normal growth and other metabolic activities of the body. The animals cannot synthesize them in their body and they are acquired through food. The mineral salts do not supply energy to the body but they are essential for protection against diseases and repairing of the damaged parts. Inadequate supply of mineral salts leads to various deficiency diseases (Das and Chakraborty, 2017)

Minerals are elements that have a metabolic role in the body. Mineral elements have a great diversity of uses within the animal body. The following mineral elements are recognized as essential for body tissue in fishes. They are Calcium (Ca), Phosphorous (P), sodium (Na), Molybdenum (Mo), Chlorine (Cl), Magnesium (Mg), Iron (Fe), Selenium (Se), Iodine (I), Manganese (Mn), Copper (Cu), Cobalt (Co), and Zinc (Zn) (NRC, 1983)

Various authors reported mineral contents in different aquatic plants Smith, (1962); Gerloff *et al*. (1966); Taylor *et al*. (1968); Boyd, (1970); Anon, (1967); Lim *et al*. (1998). Hutchison (1975) has studied the tissue chemistry of aquatic plants and reported that considerable variation in mineral composition which may be attributed to the age and type of plants sampled and the fertility of the aqueous environment. The essential nutrients and minerals imply that aquatic plants could be utilized as animal feed ingredient (Banerjee, 1988). Banerjee *et al.* (1990) reported mineral contents for various aquatic plants

Minerals are required for the normal life processes and all animals, including fish, need these inorganic elements. Fish may derive these minerals from the diet and also from ambient water. The physiological importance of minerals is well documented for humans and some animals. However, many aspects of intake, function and bioavailability of tract minerals are still unclear. Not all of the trace elements essential for higher animals (Table 3) have been described in fish (Watanabe *et al*. 1997).

Table: 3

Trace minerals important for mammals, birds and fish (Watanabe *et al*. 1997)

Cobalt	Arsenic*
Copper	Molybdenum*
Iron	Fluorine*
Manganese	Lead*
Selenium	Nickel*
Zinc	Silicon*
Chromium	Vanadium*
Iodine	Lithium*

*Limited information on fish.

Table: 4

The trace mineral requirement ranges for fish:

Mineral	Requirement*
Iron	30 – 170
Copper	1 – 5
Manganese	2 – 20
Zinc	15 – 40
Cobalt	0.05 – 1.0
Selenium	0.15 – 0.5
Iodine	1 – 4

*Expressed as mg mineral Kg^{-1} dry diet

Information on nutritional requirements of fish for trace elements is also fragmentary, particularly because many are needed only in very small amounts (Table 4) (Watanabe *et al*. 1997).

During the last few decades several works relating to element content analysis of aquatic plants and mineral nutrition of fish have been carried out by many workers throughout the world including various parts of India: Taylor and Robbins (1968) studied the amino acids contents of *Eichhornia crassipes* and evaluated its potential as protein supplement. Edwards (1980) investigated the potentially of aquatic macrophytes as food. N.A.S. (1984) attempted for making the aquatic weeds useful for a few perspectives for the developing countries.Interactions of minerals, vitamins and diet composition in fish diet was examined by Hilton (1989). Lall (1989) studied on the minerals. Steffens (1989) documented on principles of fish nutrition. Banerjee and Matai (1990) evaluated the compositions in aquatic plants of India for utilizing it as animal forage. Amino acid composition of proteins extracted from the leaves some aquatic weeds was analyzed by Dewanji (1993). Watanabe *et al*. (1988) traced the availability of minerals from fishmeal to fish. Brody (1994) studied the nutritional biochemistry of fishes. Gothberg *et al*.

(2002) investigated how heavy metals accumulated in water *Ipomoea aquatic* cultivated in Bangkok region of Thailand.

Mineral content of some wild edible leaves that are widely consumed in eastern part of Anatolia were investigated by Turan *et al.* (2003). Muta Harah *et al.* (2005) compared the aquatic macrophytes growing in natural and manmade aquatic ecosystems. Umar *et al*. (2007) studied the nutrient compositions of the leaves of water spinach. Kalita *et al.* (2007) evaluated the nutrient quality of unexplored aquatic weeds collected from north India. Rahman (2007) studied aquatic angiosperms growing in the campus of Rajshahi University. Saupi *et al.* (2009) investigated the chemical and mineral composition of the edible parts of yellow Velvet leaf. The biomolecular and phytochemical contents of three selected aquatic angiosperms were analysed by Vasu *et al*. (2009). Element contents of plants from genus *Ficus* were estimated by Khan *et al.* (2011). Mineral and heavy metal contents of aquatic plants traditionally used in Tripura of India were evaluated by Bhowmik *et al*. (2012). Saupi *et al*. (2015) analyzed the proximate and mineral compositions of *Neptunia oleracea* from Malaysia. Wasagu *et al*. (2015) evaluated the nutritional, antinutritional and minerals of *Nymphaea lotus*. We have very little information about chemical analysis of some of the common submerged macrophyte species and role of trace elements in fish nutrition.

Omojola *et al.*(2012) studied the nutritive value and potential of Aquatic plant (*Nephrolepsis bisserata* Schott) as feed resource for small Ruminant and reported the crud protein value of *Nymphaea lotus, Pistia stratioties, Eichornnia crassipes and Ipomoea aquatic* were relatively higher than the value reported for *Nephrolepsis biserrata* an aquatic plant documented to be feed resource for small ruminant. Achikanu *et al.* (2013) stated that the vitamin and mineral composition of some Nigerian leafy vegetables. Hannah and Krishnakumar (2015) analysied the mineral elements, proximate and nutritive value in *Citrullus vulgaris* Schrad (Watermelon) seed extract and recorded the proximate analysis such as fat, moisture, ash and fibre and the dietary minerals such as Iron, Phosphorus and Calcium from the seed sample. Adelakun *et al*. (2016) investigated the nutritional and phytochemical composition of ome selected aquatic plant (*Nymphaea lotus,* *Pistia stratiotes, Eichornnia crassipes* and *Ipomoea aquatic*) were collected from upper Jebba Basin, Niger state, Nigeria.

2.5 Fish Feed Formulation Using Aquatic Plant

Aquaculture and agriculture are now becoming parallel developmental activities in the field of food production (Venkateshwarlu *et al*. 2002). In fish farming, nutrition is critical because feed represents 60%-71% of the production costs (De Silva, 1985), fish nutrition Investigations are mainly directed towards reducing feed cost by manipulating the feed formulation. In India the annual production of fish is around 1.5 million tones whereas the annual requisite for fish 9.0 million tones (Das *et al*. 2017).

Natural food is available in the water body alone is not sufficient to achieve fast growth of fish (Alikunhi, 1957). The most commonly used artificial feed in India is a mixture of rice bran and oil cake. Earlier workers (Varghese *et al*.1976) have reported that this conventional feed is nutritionally inadequate. Considering the importance of nutritionally balanced and cost-effective alternative diets for fish, there is a need for research effort to evaluate the nutritive value of different non-conventional feed resources, including terrestrial and aquatic macrophytes (Edwards *et al*.1985; Wee and Wang, 1987; Mondal and Ray, 1999). Aquatic and terrestrial macrophytes have been used as supplementary feed in fish farming since the early times of freshwater fish culture (Bardach *et al*.1972) and still play an important role as fish feed in extensive culture systems (Edwards, 1987).

Aquatic plants contain high amount of minerals vitamin C and Vitamin E and all of these are important for fish nutrition especially for normal growth and development in fishes (Kalla *et al.* 2004). Ray and Das (1995) reported that it contain substantial amounts of protein and minerals. Many aquatic plants such as *Eichornia Crassipas, Hydrilla verticillata, Salvinia aculata, Ipomea quatica, Pistia spp* etc. contain fairly high amount of protein (Kalla, 2004). *Ipomea aquatica* and *Hydrilla verticillata* are currently used in many South East Asian countries as the alternative feed ingredients. Those two aquatic plants have fairly high feeding value, with moderately high protein content (Tacon, 1990).

Among the various non-conventional sources of plant protein used in fish feed, aquatic weeds are a suitable choice because certain aquatic plants are edible and they contain up to 20% crude protein and available in plenty. Along with this, the rich nutritional values of some of the aquatic plants are evident from the mineral composition (Boyd, 1969).

During the last few decades several workers relating to formulation of fish feeds from aquatic weeds / plants have been carried out by many workers throughout the world including various parts of India: The nutritive content in three water weed species was observed by Boyd (1969). Tan (1970) tested the potential of some grasses; aquatic weeds and plants for designing fish feed. Fischer (1972) studied energy balance of elements in *Ctenopharyngodon idella.* Hastings (1976) documented on fish nutrition and manufacture of fish feed. Patnaik and Das (1979) tested the utilility of selected aquatic weeds as fish feed for the rearing of carp, fry and spawn. Growth rates of common carp, catla and rohu fed different formulated diet feed was recorded by Jayaram and Shetty (1980). Venugopal and Keshavanth (1984) studied the changes in the biochemical composition of freshwater carps after introducing supplementary feeds. Edwards *et al.* (1985) incorporated composted and dried water Hyacinth in pelleted fish feed for tilapia. Wee and Wang (1987) assessed the nutritional value of Leucaena leaf in pelleted feed for Nile Tilapia. Shivananda and Devaraj (1991) compared the growth of carps fed *Salvinia* incorporated feed.

Ray and Das (1995) assessed the efficacy of pelleted fish feed incorporated with *Pistia stratiotes*, as a feedstuff for *Labeo rohita* fingerlings. Borthakur and Sharma (1998) analyzed the effect of selected non-conventional fish feed on the growth, feed conversion efficiency and body compositions in fingerlings of *Clarias batrachus.* Mondal and Ray (1999) estimated the nutritional value in fingerlings *Acacia auriculiformis* leaf after incorporating it in compounded diets for *Labeo rohita.* The efficacy of *Nymphoides* leaf incorporated diets on the growth and muscle composition in *Cirrhinus mrigala* was evaluated by Patra *et al*. (2000). Latif *et al.* (2008) did comparative study on the effects of fish meal incorporated with low cost oil seed cake as a dietary sourcd of protein for fingerlings of *Labeo rohita*.

Further, Hasan *et al*. (2009) reported that among the major submerged aquatic macrophytes *Hydrilla verticillata* has been used as fish feed. Earlier worker Tan, (1970) fed severaltypes vegetation to Grass Carp (*Ctenopharyndon idella*) in pond and found *Hydrilla* to be an excellent food because of the soft nature of the plant (low fiber) and high mineral content. Boyd, (1969) reported best growth of fish fry in the *Pistia* leaf treatment may be attributed to the higher calcium content in *Pistia* leaf. Alikunhi (1957) found that the fry of Indian carp grow best when equal quantities of zooplankton and artificial food were available to the fish.

Recently, similar observation were made by Patra *et al*. (2000) in *Cirrhinus mrigala* with Nymphoides leaf meal where 30% incorporation was found to give better growth rate than 60% incorporation. Venkateshshwarlu *et al*. (2002) studied influence of hydrophyte leaf-based feed on the growth of carp fry. Three formulated diets, *Salvinia* leaf- based feed, *Lemna* leaf based feed and *Pistia* leaf based feed used.

Bag *et al.* (2011) studied aquatic weed as potential feed for Nile tilapia (*Oreochromis niloticus* L) and its impact on fatty acid profile, Lemna (*Lemna minor*), Azolla (*Azolla pinnata*) and water hyacinath (*Eichhornia crassipes*) were used for the fish feed formulation. Sivani *et al.* (2013) studied effect of *Nymphaea* meal incorporated diets on growth, feed efficiency and body composition in fingerlings of *cyprinus carpio* L. Best growth in terms of weight gain (35.2g), specific growth rate (4.67), protein efficiency ration (PER) (2.7), feed conversion ratio (FCR) (2.5) was obtained for the test diet with 400 g Kg^{-1} nymphaea meal inclusion level. Adhikari *et al.* (2017) formulated artificial feeds for Indian carp (*Cattlea Cattla*) fry using aquatic plants (*Ipomea aquatica* and *Hydrilla verticillata*). *Hydrilla verticillata* leaf meal to be the cheapest among all the feeds as there is no commercial value for *Hydrilla* plant at present.

2.6 Photosynthetic Pigments

The compounds most important in the absorption and conversion of light energy to chemical energy are the pigments that exist within the chloroplasts or chromatophores of plants. Light initiates the process of photosynthesis through these chemicals and organelles (Devlin and Witham, 1986). Many of the colors associated with higher plants are due to the presence of pigment molecules (Goodwin, 1983, Lichtenthaler, 1987). Photosynthesis is a photobiological reaction and needs absorption of light by photosynthetic pigments (Pandey and Sinha, 2013).

The major photosynthetic pigments of higher plants can be divided into two groups, the chlorophylls and the carotenoids. Both types of pigments are present in the subcellular organelles called chloroplasts, where they are bound to proteins in the thylakoids, the photo chemically active photosynthetic biomembranes. The pigments are released in a protein-free form by grinding plant tissue in solvents such as acetone, methanol or hexane. Since the chlorophylls and the carotenoids are readily soluble in organic solvents, they are classified biochemically as lipids (Boyer, 1990). The chlorophyll content can be taken as an index of photosynthetic productivity (Arron, 1949).

2.6.1Chlorophyll pigments

Chlorophylls, the green pigments of plants, are the most important pigments active in the photosynthetic process. The most abundant plant pigments are Chlorophyll a and Chlorophyll b which occur in a ratio (a: b) of approximately 3:1 (Boyer, 1990; Devlin and Witham, 1986).

The chlorophyll a molecule has a cyclic tetrapyrrolic structure (Porphyrin), with an isocyclic ring containing magnesium atom at its center. The phytol chain of the Chlorophyll molecule extends from one of the pyrrole rings. The empirical formula of the Chlorophyll molecule is C_{55} H_{72} O_5 N_4 Mg and its molecular structure is Figure 2

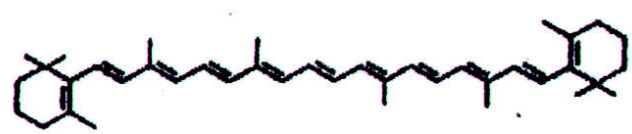
Chlorophyll a Chlorophyll b

Figure 2: Structures of Chlorophyll a and Chlorophyll b (Source: Moore, 1981)

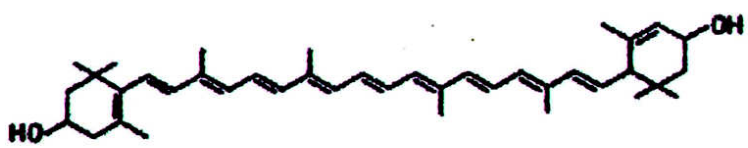
The difference between Chlorophyll a and Chlorophyll b is found at the third carbon. Chlorophyll a has a methyl group (CH_3) attached to the third carbon and Chlorophyll b has an aldehyde (HC=O) attached to the third carbon (Devlin and Witham, 1986). In the living plant cell, the Chlorophylls serve as the primary photosynthetic pigments. They absorb light in the blue (450 nm) and red regions (650-700 nm) (Boyer, 1990). The absorption spectrum of Chlorophyll provides indirect evidence of the wavelengths of light that are absorbed for the process of photosynthesis. The absorption spectra of the Chlorophylls differ slightly when in different solvents. Often the wavelength positions of the peaks may vary by a few nanometers with Chlorophyll extracted from different species (Devlin and Withem, 1986).

2.6.2 Carotenoid pigments

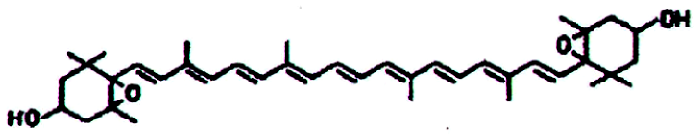
Carotenoids are lipid compounds that are distributed widely in both animals and plants and range in colour from yellow to purple (Goodwin, 1960). The second group of plant pigments, the carotenoids, can be divided into two different types, (i) the Carotenes which contain only carbon and hydrogen and (ii) the Xanthophylls which contain carbon, hydrogen and oxygen atoms in the form of hydroxyle or epoxide functional groups. The empirical formula is C_{40} H_{51} and its molecular structure is Figure 3 (Goodwin, 1960)



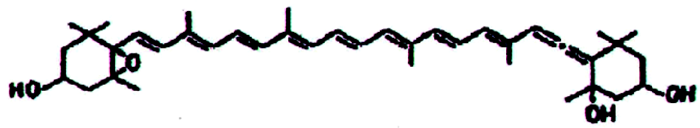
β - Carotene



Lutein



Violaxanthin



Neoxanthin

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Figure 3: Structures of major carotenoids: β- carotene, lutein, violaxanthin and neoxanthin (Source: Lichtenthaler, 1987).

Carotenoids, like chlorophyll, are located in the chloroplast and in the chromatophore as water-insoluble protein complexes (Calvin, 1959; Weir and Stocking, 1952 and Wolken, 1961). The probable roles of carotenoids in plants: (i) they protect against the photoxidation of chlorophyll and (ii) they absorb and transfer light energy to chlorophyll a (Devlin and Witham, 1986).

2.6.3 Spectral characteristics of plant pigments

The intense color of the chlorophylls and carotenoids makes them ideal candidates for absorption spectroscopy studies. Each plant pigment has a unique visible spectrum which can provide a positive identification chlorophyll a and b has absorption maxima in the 600- 675 nm range and in the 400-475 nm range. The absorption maxima for each peak are very dependent upon solvent polarity.

The carotenoids exhibit intense absorption in just one, 350-500 nm. The absorption maxima of the carotenoids vary with polarity of the solvent. β- Carotene in diethyl ether has a max of 449.8 nm, but in the more polar acetone, the max is 454 nm (Lichtenthaler, 1987)

Haskin (1942) used spectrophotometric method for the analysis of chloroplast pigments. Muztar *et al.* (1979) reported the chemical composition of Aquatic

Macrophytes, *Carotenoids*, soluble sugars and starch in relation to their pigmenting and ensiling potential. Sartory *et al.* (1984) and Jeffrey *et al.* (1997) studied on extraction of *chlorophyll a* from freshwater phytoplankton. Boyer (1990) studied the isolation and spectrophotometric characterization of photosynthetic pigments. Porra (1991) and Vicas (2010) studied the ratio of chlorophyll- a and chlorophyll- b in terrestrial plants has been used as an indicator of response to light shade condition. Porra (1989, 1991, 2002) stated that Methanol is very good extractant for chlorophyll, particularly from recalcitrant vascular plant and algae. Jeffrey *et al.* (1997) reported on phytoplankton pigments in oceanography. Michael and Nicholas (1998) also observed the pigments: chlorophyll, carotenoids in sub-merged angiosperms which varied in wide range due to ecological conditions such as light and temperature. Chen and Chen (1992) determined the carotenoids and chlorophylls in water convolvulus by liquid chromatography. Michael and Nicholas (1998) observed the pigments chlorophyll, carotenoids in sub-merged angiosperms which varied in wide range due to ecological conditions such as light and temperature.

Further, Ritchie (2006) reported that acetone gives very sharp chlorophyll absorption peaks and has great merit as the solvent for assay of chlorophylls. Tripathi (2007) studied the small proportion of chlorophyll a/b is considered as sensitive biomarker of pollution and environmental stress. Shaikh and Dongare (2008) reported that chlorophyll and Carotenoids content varied with microclimatic condition in Adiantum species Prasad *et al.* (2008) studied the photochemistry of *I.aquatic* and identified various biomolecules. Vasu *et al*. (2009) estimated the chlorophyll and Carotenoids content from aquatic plants (*E. crassipes, Ipomoea aquatica and Nymphaea pubescens*)

A few more publications related to the photosynthetic pigments of plants include those of Britton (1983); Brown *et al.* (1991) and Costache *et al. (*2012) resported that photosynthetic pigments are the substances with very different chemical structure; they are present in the form of Porphyrin pigments (chlorophyll a, b and c), carotenoids, anthocyanins and flavones. Nayek *et al.* (2014) studied chlorophylls and carotenoids from commonly grown fern species by using. Various extracting solvents and investigation revealed that diethyl ether was the best extractant solvent for chlorophyll-a and chlorophyll-b. Butnariu (2016) studied the methods of analysis (extraction, separation, identification and quantification) of carotenoids from Natural products.

2.7 Aquatic Food Crops and Nutritional Values

Macrophytes are aquatic plant species that grows in or in the neighborhood of water bodies. They are submergent, emergent or free floating and include helophytes (Bhute and Harney, 2017). Marcrophytes are important component and play a major role in primary productivity of the aquatic ecosystem. Aquatic macrophytes used nutrient and thus influence water quality. Aquatic macrophytes are the main primary producers of organic matter on which fishes thrive. They are also source of oxygen (Best EPH, 1982)

Wetlands (Locality known as 'Beel' in Assam) are continuously used by the rural farmers for production of aquatic food crops (deep water rice, fish, water chestnut, makhana, water lily, *Colocasia* sp. etc.) and non-food crops (*Cyprus* sp., *Typha* sp. *Clinogyne dichotoma*, *Aeschynomene aspera*, *Brachiaria mutica*, *Coix* sp. etc.), ornamental and beneficial medicinal plants including fish genotypes which are immense valuable, nutrition's, important and more popular in North- east states of India. Makhana or fox nut (*Euryale ferox* Salisb) under the family Nymphaceae and water chestnut (*Trapa bispinsa* Roxb). Under the family Trapaceae or oragraceae are the annual floating leaved herb (with C_3 type of photosynthesis), important aquatic food crops growing in diverse areas from tropics to the Frigid Zone with a great importance to wide sector of rural people. Fresh immature Kernels of water chestnut fruits is used as a popular article of food in raw or cooked form, which are abundant source of starch (23.3%), protein (4.7%), minerals (1.1%), amino acids, Vitamins including medicinal and therapeutic value. Mature Makhana Kernels posse's high nutritive value comprised rich in carbohydrate (76.9%), Protein (9.7%), minerals (1.3%) and fat (0.1%) are use as milk Pudding, varieties of sweetmeat dishes, vegetable curry and as costly popped form. Both are cultivated scatteredly in water bodies mainly of north eastern coastal part of the country (Pusta *et al.* 2004).

During the last few decades several works relating to aquatic and wetlands flora have been carried out by many workers in various parts of country including India. Biswas and Calder (1937) prepared a handbook plants growing in water and marsh places in India and Burma. Mirashi (1954) prepared a report on hydrophyte species of Nagpur. Subramanyam (1962) wrote a report on aquatic angiosperms. Ecological study of macrophytes of Doodhadhari Lake in Rajpur was carried out by Unni (1971). Crowder *et al.* (1977) studied the biomass, distribution, and seasonality of aquatic macrophytes in Opnicon Lake. Billore and Vyas (1981) reported on the distribution and productivity of macrophyte species in Pichhola Lake of Udaipur. Dey and Kar (1989a) documented on aquatic macrophyte species of Lake Sone of Assam. Malakar (1995) did a systematic study on aquatic angiosperm found in Cachar district of Assam. Kar and Barbhuiya (2000) recorded aquatic macrophyte species of Chatla Haor a flood-plain wetland situated in Cachar district of Assam. Macrophyte and its associated fauna existing in a flood plain aquatic system of West Bengal bearing both open and close characteristics were studied by Bhaumik *et al.* (2004). Kumar and Pandit (2005) drew a community structural design of macrophytes existing in Hokarsar wetland in Kashmir. Ghavzan *et al*. (2006) studied the effect of environmental factors on the ecology and distribution of wetland macrophytes. Devi and Sharma (2007) studied macrophyte diversity in Awangsoipal Lake of Manipur. Bhowmik *et al*. (2008) documented on aquatic and marshland plants found in West Tripura of India. Chowdhury (2009) observed and prepared a report on plant diversity and vegetation structure of wetlands in Malda district of West Bengal in India. The hydrophytes of various wetlands in Maldah district of West Bengal was recorded by Chowdhury and Das (2010).

Aquatic plants are good sources of food for man, animals and aquatic creatures thus forming an appetizing food for them and are also considered as best for conservation practices of aquatic wild life (Kiran *et al.* 2006). Several workers have conducted macrophytes survey in lakes / wetlands form different part of India Viz, Alwar lakes, Alwar, Rajasthan, Sagar Lake, Sagar, Madhya Pradesh. Sharma and Singhal (1998) recorded 11 species of macrophytes from a trophical lake, Sarraornagar Lake, Hyderabad, Andhra Pradesh. Kodarkar (1996), Meshram and

Dhande (2000) also reported on the aquatic macrophyte species of Wadali lake in Amravati and confirmed that macrophytes can effectively stimulate growth of phytoplanktons and assist in recycling organic matter as well. 25 species of macrophytes was recorded form Gujrat in Tal of Jaunpur Township in North India by Ambasht (2005). Narayana *et al*. (2005) studied the aquatic macrophytes of Hussain Sagar, Karanataka. Kiran *et al.* (2006) recorded 15 species of macrophytes from the fish culture ponds at Bhadre fish farm, Karnataka. Game and Salaskar (2007) recorded the macrophytes on Malchmali Lake, thane, Maharstra.

Further, Das (2013) recorded 128 macrophyte species belonging to 100 genera and 50 families from the Kamrup district of Assam. Dhore and Luchare (2014) recorded 15 species of macrophytes in Yavatmal district. Dutta *et al.* (2014) studied diversity status of aquatic macrophyte in Kapla Beel of Assam. Total 68 plants species, 49 genus and 28 families were recorded. Deka and Sarma (2014) recorded 137 species, 114 genera and 53 families from wetlands in Nalbari district of Assam. 228 plant species belonging to 153 genera and 57 families from the five were listed by Sarma and Borah (2014) from Sonitpur district of Assam. Bhute and Harney (2017) listed 15 species belonging to 5 groups and 14 families from the Nagrala Lake of Bhadrawati Chandrapur (M.S.).

Several workers studied the nutrient content of aquatic weeds. The formulation and processing of fish diets were performed by Pike and Brown (1967) documented on nutrition as an integrated approach. Moynard and Loosli (1969) prepared a chart for animal nutrition. Ogino and Chen (1973) prepared feed with protein nutrients in fish. Cho (1985) evaluated the effects of protein intakes on the metabolic activities and net energy value of fish feed diet. Lovell (1979) formulated planned diets for aquaculture species and Wilson (1995) evaluated the nutritional status and feeding regime of fish. Of all the plant protein feedstuff, soyabean meal was used as the major protein source in many fish diets (Lovell, 1989). Bulletin of Food and Agriculture organization (FAO) and United Nation of Development Programme (UNDP) had also mentioned about feed formulation. Boyed (1968) determined the crude protein content samples of 43 species of aquatic plants and stated that protein content declined rapidly while maturity.

Further, Bhosale *et al*. (2010), in his experiment 33% crude protein level was scheduled in the formulated diet which was very near to dietary protein of 34% for the same fingerlings of *Labeo rohita* (Khan *et al.* 1991). Silva and Gunasekera (1991) conducted an experiment on the economically optimal growth of *Labeo rohita* comprising with 31% crude protein diets. In another study significantly improved growth of *Labeo rohita* at 29% of protein level (Mohanty and Swamy, 1996) was reported. Therefore, to get an optimal growth response of the fish species, selection of 33% crude protein level in the diet was a justified amount. Boyd (1968 and 1969) evaluated composition of possible feed stuffs. The results of such studies would be helpful while considering the utilization of aquatic plants for particular needs. Ray and Das (1995) demonstrated that aquatic plants are sources of food that consist substantial amount of protein and minerals.

Venkateshwardu *et al*. (2002) estimated the proximate composition of *Salvinia*, *Pistia* and *Lemna* and found that highest protein has been found in *Lemna* (15.33%). Kalla *et al*. (2004) reported that many aquatic plants such as *Eichhornea crassipes*, *Hydrilla verticillata, Salvinia aculata, Ipomea aquatica, Pistia spp*. etc. contain high amount of protein. Umar *et al.* (2007) analysed the nutritional composition of water spinach (*Ipomoea aquatic* Forsk) leaves and the proximate composition and mineral elements were determined, moisture (72.83%) ash (10.83%), crude lipid (11.00%) crude fibre (17.67%), carbohydrate (54.20%) and crude protein (6.30%) estimated. Kalita *et al*. (2007) reported aquatic weeds as *L. minor*and *I. reptans* are important source of vitamins, minerals and proteins, and are suitable for incorporating them in fish diet. Sarker *et al*. (2000) studied percent weight gain *L. rohita* fed on five different diets A, B, C, D and E during 60 days feeding trail. Bhosale *et al*. (2010) in his experiment soybean (*Glycine max*) has been selected as the raw material for formulation of fish feed. Bag *et al.* (2011) evaluated the biochemical composition of *Lemna*, water hyacinta and *Azolla*. The nutritional value of aquatic weeds namely: Lemna (*Lemna minor*), Azolla (*Azolla pinnata*) and Water hyacinth (*Eichhornea crassipes*) were analyzed by Bag *et al*. 2012.

Recent investigations on the proximate composition of aquatic plants weeds include those of Saupi *et al.* (2015) determined the proximate composition of

Neptunia oleracea. Moisture (83.75% to 86.25%), ash (1.05 to 1.7%), crude protein (3.01 % to 3.23%), crude fat (0.25% to 0.44%) and crude fiber (2.30% to 2.66%, Wasagu *et al*. (2015) analyzed the nutritional, anti nutritional and mineral composition of *Nymphaea lotus* (Water lily) and found that it contained crude lipid (2.00% to 9.33%) ash (2.67% to 26.7%), moisture (6.00 to 9.00%) crude protein (1.02 to 5.82%) and crude fiber (5.50% to 24.33%).