Chapter-1

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1.1 Aquatic Fish Food Crops

Aquatic plants are those whose photosynthetically active parts remain permanently or at least for several months each year submerged in water or floating on water surface (Singh, 2006).

Aquatic and wetland (locally known as Beel) plants are mostly confined to the marshes and wetland habitats(Cowardian *et al*.1979).The large aquatic plants also known as 'aquatic macrophyte' are the important source of food, fodder, herbal medicine and domestic household materials for the people residing in its vicinities (Deka and Sarma,2014).The swampy, fertile, productive wetlands 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 (*Cyperus* spp., *Typha* spp., *Clinogyne dichotoma, Aeschywomene aspera, Brachiaria nutica, Coxis sp.* (Puste *et al.* 2004).

Aquatic fish food crops or aquatic macrophytes have been used as supplementary feeds in fish farming since the early times of fresh water fish culture (Bardach *et al.*1972) and still play an important role as fish feed in extensive culture systems (Edwards,1987). Ray and Das (1996) demonstrated aquatic plants a source consisting substantial amounts of protein and minerals.

Aquatic fish food crops/plants such as *Eichornia crassipes*, *Hydrilla verticillata*, *Salvinia aculata*, *Ipomea aquatic*, *Pistia* sp. etc. contain fairly high amount of protein. Aquatic plants possesses high amount of vitamin C, Vitamin E and minerals that are essential for fish nutrition and for the normal growth and developmental activities in fishes (Kalla *et al.* 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).

Aquatic macrophytes are edible and they contain up to 20 percent crude protein and are available in plenty. Along with this the rich nutritional values of some of the aquatic plants is evident from the mineral composition (Boyd, 1969).

1.2 Fish-aquatic Food Crops Diversity

Biodiversity is the variation of life forms within a given ecosystem, biome or on the entire earth. The biodiversity found on the earth today consists of millions of distinct biological species. It includes the variability of species in terrestrial, aerial and aquatic habitats, the diversity of ecosystems and the diversity of genes they harbor. It is an essential component of the nature and it ensures the survival of various species by providing welfare resources.

There are 12 “Mega diversity” countries in the world. Besides, IUCN also declared many areas around the world to be called as “Biodiversity Hotspots”. India is one of the total 12 “Mega Diversity” countries of the world. Bio-diversity hotspots include mainly the Eastern Ghats, the Western Ghats and the North-Eastern hills.

Northeast India represents the transition zone between the Indian, Indo-Malayan and Indo-Chinese bio-geographic regions and a meeting Place of the Himalayan Mountains and peninsular India. Northeast India is thus the geographical ‘gateway’ for much of Indian flora and fauna, and as a consequence, the region is one of the richest in biological value. The northeastern region has always been in focus for its high biodiversity and the region has been a priority as it leads many conservation agencies of the world (Barooah and Sarma, 2016).

A large part of Assam is covered by wetlands rich in both flowering and non-flowering plants. The diversity of aquatic fish food crop species of Assam numbering around 100 identified so far, are of the types- free floating, suspended submerged, anchored submerged, anchored with floating shoots, anchored with floating leaves, emergent amphibious and wetland hydrophytes of the aquatic plants,

Eichhornia crassipes, Nymphaea, Ottelia, Jussiaea, Pistia stratiotes, Azolla pinnata, Monocharia hastata, species of *Cyperus, Scirpus, Ipomea aquatic, Nelumbo nucifera, Trapa natans* var *bispionsa, Euryle ferox* etc. are abound in

many wetlands. Recently *Ipomea carnea* (commonly known as panibhotera) has become the most dominant weed of marshy lands and also of ecotone regions between aquatic and terrestrial zones in almost all parts of the state (Bhagabati *et al.* 2006).

1.3 Ox-bow Lakes and Kalpani Beel

The ox-bow lakes or meander cut-offs are the crescent shaped body of water located along the streams. These are the results of neck cut-offs from the meandering channels. Wetlands of this type sometimes have feeder channels controlling the inflow and outflow of water and are usually attached with typically meandering rivers. Some important wetlands of this category are the Morikalong and Patoli beel in Nagaon district, Mer beel in Golaghat district and Guruajan in Morigaon district of Assam, India. Kanwar Taal lake of Bihar, in India, is the largest ox-bow lake in Asia with fresh water, Lake Chicot of Arkansas state is the largest ox-bow lake in the North America formed by Mississippi river (21 miles long and ¾ mile wide) (Bhagabati *et al*. 2011; Dutta, 2012)

A total 861 number of ox-bow lakes / cut off meanders are observed throughout the state of Assam in India, covering an area of 15460.60 ha which constitutes 0.20 percent of the entire geographical area of Assam and 15.27 percent of areas under wetlands (Dutta, 2012).

Kalpani Beel (locally known as “Mora Manas”) an ox-bow lake formed by the River Manas, a tributary originated in Bhutan of Eastern Himalayan Biodiversity hotspot. It is located in Chirang district, Western part of Assam in India which falls under the Manas Biospher Reserve, UNESCO. It is about 170 Km. far away from the capital, Guwahati and is 15 Km. North to 31 No.National highway.

Kalpani Beel is geographically located between 26.54800° to 26.55037° N latitude and 90.80825° to 90.82676° E longitude, altitude 76.30 meter in the eastern part of the district. Kalpani Beel is the only fresh water Beel (wetland) of the district. Total area of the Beel covers 56.1656 hectares. The Beel has connecting channel with river Manas. It is an important tributary of the river Brahmaputra (originated from the Manasarvar lake of Tibet).

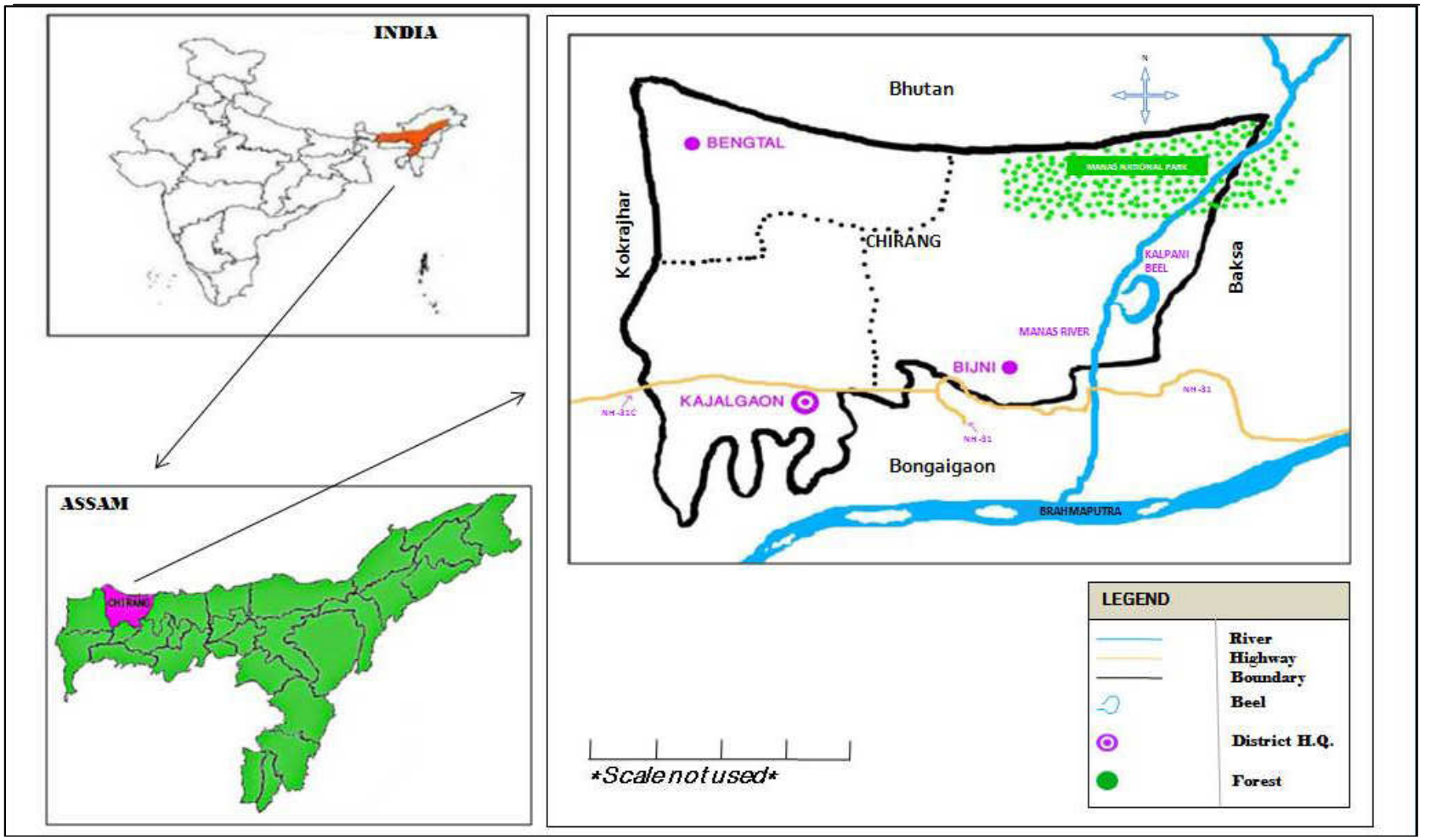

Figure 1. Location map of Kalpani Beel

1.4 Manas River

Assam is a land of rivers. The Manas River is a transboundary river in the Himalayan foothills between Southern Bhutan and India. It is named after 'Mansa' the serpent God in Hindu mythology.

It is the largest river system of Bhutan. It lies in longitude 26°55.16′ 39.5″ N latitude 90°88.95′ 49.3″ E. The total length of the river is 376 Kilometres (234 mi), flows through Bhutan for 272 Kilometers (169 mi) and then through Assam for 104 Kilometers (65 mi) before it joins the Brahmaputra River at Jogighopa of Bongaigaon district of Assam, India.

The river originated in the Bhutan, flows through Baksa, Chirang and Bongaigaon district of Western Assam from North to South and merges with the mighty Brahmaputra (Das, 2013; Sharma, 1993).

1.5 Fish Diversity of Kalpani Beel

Kalpani Beel is one of the most unique wetland in the Chirang district of Assam, India. Around 55 species of fish inhabit this Beel and a majority of them depends on the plankton diversity in the Beel for their nutrition. As such many poor fishermen living around the Beel are depended on it for their livelihoods. Not only the fisherman but most of the people living around the Beel are highly knowledgeable and have much information regarding the fish species and macrophyte diversity in Kalpani Beel. According to them some of the commercially important fishes found and harvested from the Beel are *Catla catla, Cirrhinus mrigala, cyprinus carpio, Labeo rohita, L. gonius, L. calbasu, Osteobrama cotio, Anabas testudineus, channa striata, C. punctatus, Spetata, seenghala, Claries batrachus, wallago attu* etc. The fish harvested from the Beel have high demand in the markets due to their better taste in comparison to artificially farmed fishes and their high palatability.

1.6 Aquatic Plant Diversity of Kalpani Beel

Aquatic plants are primary source of food for many small as well as big fishes in Kalpani Beel. Many fishes depend on the rich diversity of macrophytes in the Beel for their nutrition. Likewise, the variety of macrophytes found in the Beel provides

the options for the variety of fish species for selecting their preferred and favorite macrophytes. As informed by the informants living around the Beel it was found that among the variety of macrophytes six macrophyte species namely *Hydrilla verticillata, Eichhornia crassipes, Ipomoea aquatica, Nymphea rubra, Pistia stratiotes and Trapa natanus* were most preferred by fishes in Kalpani Beel.

1.7 Importance of Wetlands and Climate Change

Wetlands are considered to have unique ecological features which provide numerous products and services to humanity (Prasad *et al*. 2002). Ecosystem goods provided by thewetlands mainly include: water for irrigation; fisheries; non-timber forest products; water supply and recreation. Major services include: carbon sequestration, flood control, groundwater recharge, nutrient removal, toxics retention and biodiversity maintenance (Turner *et al.* 2000).Wetlands are the storehouse of biological wealth. The biological wealth rich wetlands containing diverse flora and fauna may yield food, fodder, fuel and medicine etc. thereby providing subsistence for millions of people residing in the vicinity (Sarma, 2008).

Global climate change is expected to become an important driver of loss and change in wetland ecosystem (MEA, 2005; UNESCO, 2007).These findings are important for Indian subcontinent where the mean atmospheric temperature and frequency of occurrence of intense rainfall events has increased, while the number of rainy days and total annual amount of precipitation have decreased due to increase in the concentration of greenhouse gases such as CO_2, CH_4 and N_2O in the atmosphere (Bates *et al*. 2008).

1.8 Wetlands Classification

Classification of wetlands has been a task, with the commonly accepted definition of what constitutes a wetland being among the major difficulties. A number of national wetland classifications exist. In the 1970s, the Ramsar convention on wetlands of international importance introduced a first attempt to establish an internationally acceptable wetland classification scheme (Islam and Rahmani, 2008).

1.8.1 Ramsar Classification System

The Ramsar classification of wetlands types is intended as a means of fast identification of the main types of wetlands for the purpose of the convention.

The wetlands are classified into three major classes:

- Marine / coastal wetlands
- Inland wetlands
- Human –made wetlands

These are further subdivided by the type of water: fresh / saline / brackish / alkaline; and may be further classified by the substrate type of other characteristics (Islam and Rahmani, 2008)

1.8.2 State System of Classification, Assam

In 1992, the Assam Remote sensing Application Centre (ARSAC), Guwahati, Assam jointly with Assam Science Technology & Environment Council (ASTEC), Guwahati and the Space Application Centre of the Indian Space Research Organization (ISRO), Ahmedabad, provided classification system that divided the wetlands in Assam into six categories:

1. Pond or Lake
2. Ox-bow lake or Cut- off meander
3. Waterlogged area
4. Marsh or Swamp
5. Tank and
6. Reservoir

Among them first four are considered as natural water bodies and the last two as man made.

Table 1. Area estimates of wetlands in Assam (Source: National Wetland Atlas: Assam, 2010)

Wetland category	Number of wetland	Total wetland area (in ha)	% of wetland
Inland Wetlands Natural			
Lakes / Ponds	1175	51257	6.71
Ox-bow lakes / cut-off meanders	873	14173	1.85
High altitude Wetlands			
Riverine Wetlands	139	4258	0.56
Waterlogged	2461	47141	6.17
River / stream	213	637164	83.63
Inland Wetlands Man-made			
Reservoirs / Barrages	2	2833	0.37
Tanks / ponds	180	921	0.12
Waterlogged	54	544	0.07
Sub-total	5097	758291	99.20
Wetlands (<2.25 ha) mainly tanks	6081	6081	0.80
Total	11178	764372	100.00

1.9 Research Components on Wetlands

The study on the wetlands in India started in the 1970s. Various types of studies were conducted. These studies include the following aspects:

- Limnology
- Fish Diversity / Fauna
- Aquatic vascular plants diversity
- Mineral present in aquatic plants
- Photosynthetic pigments.
- Biotechnological approach in formulation of artificial fish food.

Majority of research work on wetland management in India relates to the limnological aspect and ecological/ environmental economics of wetland management.

1.9.1 Limnology

Limnology is the study of inland waters- lakes (both freshwater and saline), reservoirs, rivers, streams, wetlands and groundwater. The wetland limnological studies have been carried out by researchers throughout the world. Edmondson (1966) investigated the changes in the oxygen levels in an oxygen deficit Lake of Washington. Beaver *et al*. (1981) studied the changes in thermal regimes of Florid Lakes in USA. Boyd (1982) devised strategies for water quality management for pond fish culture. Barrion *et al*. (1982) studied the water quality of Lake Lemen in Geneva. Chitranshi *et al.* (1986) did a comparative ecological study on ox-bow lakes formed by the river Burhi in Gandak. Romo *et al*. (1994) performed the population dynamics and ecological studies of subdominant phytoplanktons residing in shallow hypertrophic lake. Nadoni *et al.* (2000) tested water quality index in Amani tank, London and Chen *et al*. (2000) studied on how heavy metals accumuled as food web component. Studies in this field have also attracted attention in India in recent years. Ganapati (1973) in South India reported about the ecological problems faced by man-made Lakes. Adoni (1975) presented a view on the microbiological constituent of Sagar Lake. Khan *et al*. (1994) studied physical and chemical limnology of Lake Kaptai, Bangladesh. Kumar (1997) studied about the limnological characteristics of Kunjwani pond in Jammu. Kaushik and Saksena (1999) reported the physico-chemical and limnological characters of water bodies from cental India. The physico-chemical conditions of the major effluents points of the Nambul River in Manipur was studied and documented by Devi (2005).

The physico-chemical quality in Beel water of Morigaon district in Assam was studied by Kalita *et al*. (2006). Kosygin *et al*. (2009) studied the ecology and conservation status of Loktak Lake in Manipur. Singh *et al.* (2000) observed the monthly variations in the physico-chemical properties of sediments in Karwar Lake located in North Bihar. Manjara *et al*. (2010) analysed water quality by measuring the physico-chemical properties of Tamdalge tank situated in Kolhapur district of state Maharashtra. Shraddha (2011) evaluated the water quality of river Narmada at Hoshangabad city referring its physico-chemical parameters. The physico-chemical status of water bodies that were under anthropogenic influences at Sagar city was assessed by Pathak *et al*. (2012). Deb *et al*. (2012) reported the

status of Udali Beel located in Karbi Anglong District of Assam and Laishram *et al*. (2014) studied the status of water quality of Laktak Lake, Manipur.

1.9.2 Fish Diversity

Floodplain wetlands, commonly known as Beels, are highly productive aquatic ecosystems with distinct environmental characteristics and after enormous scope for fisheries enhancement through holistic management. Beels are highly productive aquatic ecosystems and provide breeding and nursery grounds 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 Bhattachariya, 2003).

Different earlier workers / researchers like Jhingran (1992) studied about the Fish and Fisheries of India. Dey (1982) did a critical analysis of the status of fish and fisheries in Assam. Lahon (1983) reported the limnological characters and fisheries of commercial Beels in Assam. The limnology and fisheries of the Lake Sone of Cachar district in Assam, India was described by Kar (1984). Nath and Dey (1997) studied on the fish fauna and fisheries in North-East India. Bhattacharjya *et al*. (2000) authenticated and prepared a list of threatened fish species of Assam. Sen (2000) studied on the diversified fish fauna of North East India based on their distribution, occurrences and status. Bhowmik and Ayyappar (2000) presented a report on the status of biodiversity conservation in North east India. Sarkar and Ponniah (2000) evaluated the potential of North East Indian fishes. Bordoloi and Hazarika (2015) studied the biodiversity and conservational status of Ichthyofauna species in Doria Beel of Majuli, Assam. The diversity Ichthyofauna in wetlands of upper Assam was described by Biswas and Choudhury (2008). Bhuyan *et al*. (2009) studied the hydrobiology and status of fishery of Sondoba Beel in Morigaon of Assam. Barbaruah *et al*. (2012) studied the diversity of planktons, fishes and Macrophytes of Monoha Beel of Morigaon district in Assam

1.9.3 Aquatic Vascular Plants 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 bodies and wetlands. In general, these represent plants which are found in around the water bodies (Das, 2013). The aquatic macrophytes are the important source of food, fodder, herbal medicine and domestic household materials (Pandit, 1984).

During the last few decades several works relating to aquatic macrophytes have been carried out by researchers throughout the world. Denny (1985) studied about vegetations in wetlands and the associated plant life form in them. Cowardin *et al.* (1979) classified the wetlands and deep water habitats in United States. Keddy (2000) also studied studied the ecology of wetlands in various parts of India. Biswas and Calder (1937) prepared a handbook of common marsh and water plants found in India and Burma. A study on hydrophytes of Baroda was performed by Chavan and Sabnis (1961). Unni (1971) performed an ecological study on the macrophytes of Doodhadhari Lake in Rajpur. Sharma (1993) described the geo-ecology Beels and swamps of Morigaon and Nagaon districts in Assam. Singh (2006) documented the contributions gathered from the aquatic flora of Varanasi. The diversity of macrophytes in Awangsoipal Lake, Manipur, was described by Devi and Sharma (2007). Sarkar *et al*. (2008) wrote about some of the medicinal value of wetland angiosperms that are used by Bodo tribe in Kamrup district of Assan. Sarma and Borah (2014) performed a phytosociological investigation of the aquatic macrophytes in selected five wetlands of Sonitpur district in Assam and Deka and Sarma (2014) presented the status of aquatic macrophytes of wetlands in Nalbari district of Assam.

1.9.4 Mineral Present in Aquatic Plants

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 wetlands from small ditches, ponds, irrigation canals, sewage lagoons, streams, rivers, water reservoirs, shallow lakes, and marshes to swamps (Muta Harah *et al*. 2005). Several authors (Banarjee and Matai, 1990; Boyd, 1968) have emphasized the potential of aquatic plants as food and feed. The presence of

substantial quantities of minerals in aquatic macrophyte as required for fish nutrition was testified by Kalla *et al*. (2004).

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 Ca, P, Na, Mo, Cl, Mg, Fe, Se, I, Mn, Cu, Co and Zn (NRC, 1983). Fish may derive these minerals from the diet and from ambient water (Watanbe, 1997).

During the last few decades several works relating to elements content, analysis of aquatic plants and mineral nutration of fish have been carried out by many works throughout the world including various parts of India. Boyd (1968) estimated the potentiality of fresh water plants as a source of protein for nutrition. Banarjee and Matai (1990) evaluated compositions in aquatic plants for utilizating it in animal forage. The amino acid contents of proteins extracted from the leaves of some aquatic weeds were analyzed by Dewanji (1993). Gowda *et al*. (2004) estimated the micronutrient content of some conventional and unconventional tropical feed resources in southern India. Umar *et al*. (2007) analyzed the nutritient content of the leaves of water spinach. Nutritional quality of four aquatic weeds found in northeast India were evaluated for formulating a cost-effective fish feed. (Kalita *et al*.2007).Vasu *et al*. (2009) evaluated the biomolecular and phytochemical composition of three aquatic angiosperms. Bhowmik *et al*. (2012) determined the mineral and heavy metal content of traditionally important aquatic plants from Tripura and Wasagu *et al*. (2015) investigated the nutritional, antinutritional and mineral composition of *Nymphaea lotus*.

1.9.5 Photosynthetic Pigments

It is hard to conceive of life originating or existing without the absorption and conversion of radiant energy to chemical energy. As Glass (1961) stated, “Life is a photochemical phenomenon.” The compounds most important in this 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 (Devline and Witham, 1986). Considerable work has been done on photosynthetic pigments of aquatic

plants in India and abroad. Lichtenthaler and Wellburn (1983) determined the presence of chlorophyll a and b and total carotenoids in leaf extracts using different solvents. Rowan (1989) studied the photosynthetic pigments of algae. Boyer (1990) after isolation spectrophotometrically characterized photosynthetic pigments. Vicas *et al.* (2010) using different solvents identified the chlorophyll and carotenoids pigments of Mistletoe leaves. Chen and Chen (1992) determined carotenoids and chlorophylls in leaves of water convolvulus using liquid chromatography. Shaikh *et al*. (2008) analyzed the photosynthetic pigments in *Adiantum lunulatum.* Vasu *et al.* (2009) analyzed biomolecular and phytochemicals in three aquatic angiosperms. Butnariu (2016) developed methods of analysis for the extraction, separation, identification and quantification of carotenoids from natural products.

1.9.6 Biotechnological Approach in Formulation of Artificial Fish Food

Biotechnology is broadly defined as "using living organisms or their products for commercial purposes". Biotechnology has been practiced by human society since the beginning of recorded history in such activities as baking bread, brewing alcoholic beverages or breeding food crops or domestic animals. The European Federation of Biotechnology (EFB) defines biotechnology as "the integration of natural science and organisms, cells, parts thereof and molecular analogues for products and services".

Many aquatic plants contain fairly high amount of protein. 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 (Edward *et al*. 1985; Wee and Wang, 1987, Mondal and Ray, 1999)

During the last few decades several workers/ researches in India and abroad has been working in this field. Boyd (1969) investigated the nutrient value of three water weeds. Composition and nutrient values of some plants, grasses, and aquatic weeds were tested as diets for fishes. Patnaik and Das (1979) studied the feasibility of utilizing some aquatic weeds as fish feed for the rearing of spawn, fry and carp. Shivananda and Devaraj (1991) compared the growth of carps between carps fed

with *Salvinia* based feed and carps fed the conventional feed. Borthakur and Sharma (1998) studied the efficacy of non-conventional fish feed on the feed conversion efficiency, growth and muscle composition of *Clarias batrachus* of fingerlings. Patra *et al*. (2000) tested the effects of *Nymphea* leaf meal incorporated diets on the growth and muscle composition of *Cirrhinus mrigala*. Also, the effects of *Nymphaea* meal incorporated diets on the feed efficiency, growth and muscle composition in fingerlings of *Cyprinus carpio* was evaluated by Sivani *et al*. (2013).Venkateshwarlu *et al*. (2002) evaluated the influences of leaf-based hydrophyte feed on the growth parameters of carp fry. Adhikari *et al*. (2017) formulated artificial feeds using aquatic plants for Indian carp fry.

1.10 Objectives

Specific objectives of the study were:

1. To study seasonal variations of water quality in Kalpani Beel.
2. To study the fish diversity of Kalpani Beel.
3. To study Macrophyte diversity of Kalpani Beel.
4. To estimate the mineral content in selected aquatic plants.
5. To study the photosynthetic pigments of *Hydrill verticillata* plant.
6. To formulate artificial fish feed using aquatic plants and evaluate their efficacy in fish growth.