International Journal of Plant and Environment
Vol. 4, No. 2 (July, 2018), 88-96

Eroding Traditional Knowledge Systems Plea Scientific Validation: Ecological Characterization of Traditionally Managed Semi-Deep Water Rice Field Agro-ecosystem in Barak Valley, Assam, Northeast India

Malabika Bhattacharjee and Tapati Das*

Department of Ecology and Environmental Science, Assam University, Silchar-788011, INDIA

Publication Info

Article history:
Received: 31.03.2018
Accepted: 31.07.2018
DOI: 10.18811/ ijpen.v4i02.11

Key words:
Agro-ecosystem
Ecological characterization
Plankton
Rice variety
Rice-stem epiphyton
Traditional ecological knowledge

Corresponding author:
Dr. Tapati Das
Mob.: +91-9435500824
Email: das.tapati@gmail.com

Abstract

Traditional ecological knowledge (TEK) systems illustrate various ways and means of natural resource utilization and management, which has come into being through keen observations as well as the age-old trial and error methods. However, such knowledge systems are gradually eroding due to various reasons. Proper documentation, characterization, scientific validation, and popularization of such knowledge systems would help in preserving them for posterity. The present study characterizes the ecological attributes of a traditional rice farming system called *Asra* in Karimganj district of Barak Valley, Assam. The objective was to investigate the water properties and community composition of plankton and rice stem epiphyton of the water logged *Asra* rice field agro-ecosystem. The substantial contribution of *Asra* rice field ecosystems in maintaining the overall biodiversity of the system has been highlighted in the present study. The study revealed the presence of 77 genera of phytoplankton and 55 genera of rice stem phyto-epiphyton, which belonged to six major classes viz., Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae, Xanthophyceae and Zygnemophyceae. Besides, 29 genera of zooplankton and 14 genera of rice stem zoo-epiphyton belonging to five major groups viz., Protozoa, Cladocera, Copepoda, Ostracoda and Rotifera were also recorded. The study shows that the *Asra* rice fields are rich repository of plankton and rice stem epiphyton, the natural live food resources for fish. The study emphasizes on conservation of traditional farming system like *Asra*, and stresses on the need for sustainable utilization of the existing bioresources in such system by introducing the concurrent practice of rice-fish culture in the study area.

1. Introduction

Traditional ecological knowledge (TEK) consists of the body of knowledge, beliefs, traditions, practices, institutions, and worldviews developed and sustained by indigenous peasant, and local communities in interaction with their biophysical environment (Toledo, 2002; Berkes, 2004). TEK systems have great contribution in sustaining biodiversity, providing ecosystem services (Gadgil *et al*., 1993; Reid *et al*. 2006; Boafo *et al.,* 2016), and building resilience in the face of global climate change (Folke, 2004; Berkes and Davidson-Hunt, 2006; Ceuretick *et al.,* 2011; Gómez-Baggethun *et al.,* 2012). TEK can improve the livelihoods of TK holders and communities (McDade *et al*., 2007; Reyes-García *et al.*, 2008). However, TEK is under threat in many parts of the world because of the influences of formal schooling and loss of local languages (McCarter and Gavin, 2011; Reyes-García, 2013), dominant religions (Tang and Tang, 2010), changes in land use (Kingsbury, 2001; Gray *et al*., 2008), market integration (Godoy *et al*., 2005), loss of access to resources through conservation programs (Gómez-Baggethun *et al*., 2010), mechanization of resource systems (Brodt, 2001), and industrialization and globalization processes (Turner and Turner, 2008; Gómez-Baggethun, 2009). Such loss reduces the information available to solve many contemporary environmental issues including climate change. Scientific validation of traditional knowledge systems, especially in the agricultural sector, may help in creating awareness amongst the people on the ecological importance of TEK as well as its economic implications.

India is blessed with diverse rice varieties and associated traditional knowledge. India's varietal diversity can be considered the richest in the world with a total number of cultivars estimated to be around 200,000 (Banerjee, 2013). Indian traditional cultivars are famous for their nutritive and medicinal values (Das and Das, 2006), aroma and grain length (Subudhi *et al*., 2012). They are also more resistant to diseases and pests and are more resilient to environmental stress (Saxena and Singh, 2006; Banerjee, 2013). However, indigenous rice resource is depleting fast due to various reasons viz., overexploitation, human-induced changes in their environment, genetic manipulation in plants, Government policies, commercial breeders, green revolution and introduction and aggressive promotion of HYV (High Yielding Variety) by government, monocropping in agriculture and erosion of traditional knowledge (Friis-Hansen, 1996; Sebby, 2010). Currently, changing climate and erratic weather events have brought catastrophic results in our agronomy with HYV in contrast to that of indigenous seeds, which have better capacity to adapt to such extreme conditions (Das and Das, 2006). Therefore, scientific studies and validation of such traditional rice farming system are essential for their protection, intellectual appreciation, and mass acceptance.

The state of Assam in northeast India is traditionally a rice-growing area. The variation in microclimate across the state has resulted in the evolution of a large number of indigenous rice varieties not found anywhere else in the world (Dutta Deka *et al.*, 2014). Karimganj, border district of Assam with Bangladesh, is a water base and flood prone district. Almost 30% of the district remains water covered for more than 6 months (District Irrigation Plan, 2016-2021 Karimganj, Assam). The terrain of the district consists of flood plains, wetlands, hills and forests. Cultivation of *Asra*, a semi deep water indigenous rice, is practiced during monsoon (i.e. April-May) to post-monsoon (i.e. November-December) seasons in low lying area particularly along riparian area of rivers and wetlands which remain inundated during most of the time of the cropping period because of heavy rainfall and subsequent accumulation of the rain water in such area. Cultivation of *Asra* rice is done particularly in area where cultivation of all other rice varieties will lead to a chance crop production because of sudden submergence of such area due to erratic rainfall. Since traditional varieties of paddy under *Asra* have the unique ability to grow rapidly by elongation of internodes with the rising water level cultivation of such rice varieties may be the most suitable option in such area in terms of proper utilization of such land resources and sustainable rice production.

Considering the above, the present study was undertaken to investigate the ecology of *Asra* rice fields with special reference to planktonic and rice stem epiphytic communities which has remained unexplored. A proper understanding of such studies in *Asra* rice fields during its aquatic phase would help the skateholders in identifying opportunities for aquaculture practices. Such scientific interventions would add up the prospect for identifying the potential of such land area in terms of its other ecosystem services and values for maintaining the livelihood of the traditional farmers in the region.

2. Materials and Methods

2.1. Study area

The present study was carried out in Karimganj district of Barak Valley, Assam. We selected two sites (Fig. 1) under *Asra* rice cropping season. The distance between the two sites was ~2414 m. Within each site, three plots of approximately similar area (1947 ± 80 m^2) were demarcated for sampling. Thus, six representative plots were sampled for the present study. The three plots of each site were separated by distance of ~402 m.

2.2. Sampling procedure

A simple random sampling approach was followed for studying different physico-chemical and biological parameters of the *Asra* rice field environment. Sampling was undertaken at monthly intervals during the aquatic phase of the cropping season i.e., from June 2012 to September 2013.

Samples of water, plankton and rice-stem epiphyton were collected from the selected rice fields. Physical properties

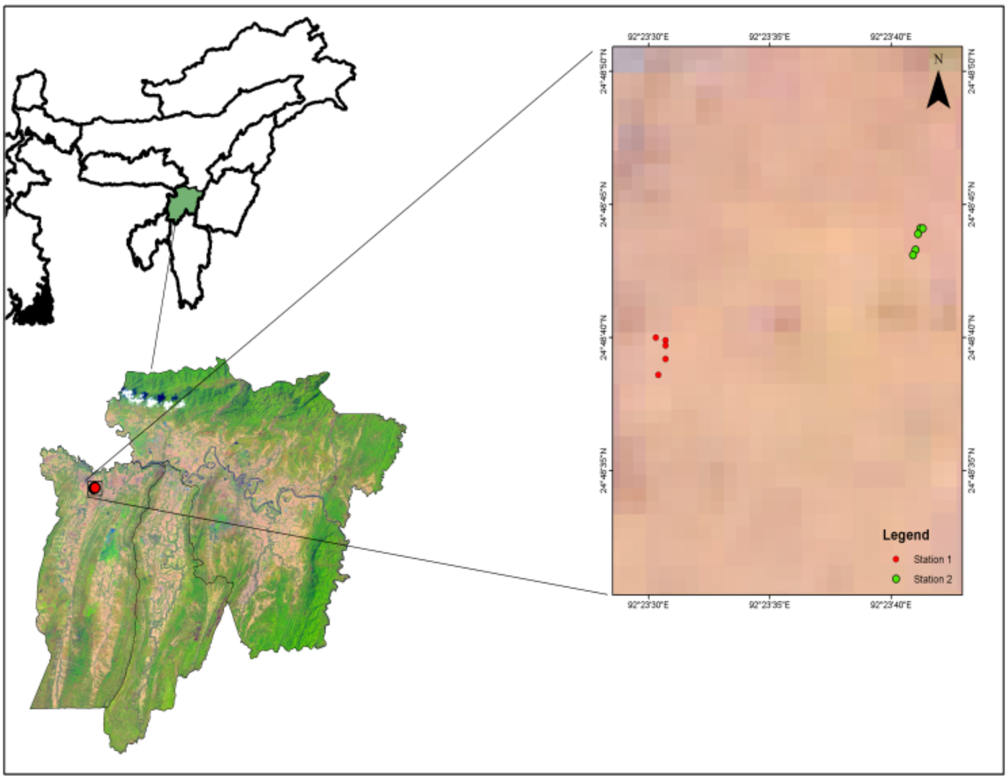

Fig 1: Map showing the study area and sampling stations in *Asra* rice fields.

pertaining to the rice field environment viz., air temperature (AT), water temperature (WT), and sediment temperature (ST) were recorded using a mercury bulb thermometer (0-50°C). Water depth (WD) was recorded using a measuring pole. Samples for dissolved oxygen (DO) and biological oxygen demand (BOD) for 3 days at 20°C were collected in BOD bottles following standard procedure (APHA, 2012). For analysis of other chemical parameters, water samples were collected in PVC bottles. Samples for estimation of 'chlorophyll-a and plankton' in the rice field water were collected in PVC bottles by filtering out 25 liters of rice field water through plankton net of mesh screen size 45μm. Plankton samples thus collected were immediately preserved in glass vials using 2ml 4% formalin. Rice stem epiphyton samples were collected randomly by gently scrapping from a known area of 10 numbers of cut submerged rice stems using a fine scalpel. The scrapped samples were then preserved in glass vials using 2ml 4% formalin. All the samples were later on brought to the laboratory for their analysis.

Table 1: Physico-chemical properties of water in the Asra rice fields.

Parameters	Mean±SD	Range
Air temperature (°C)	34.59±2.93	28.33-38
Water temperature (°C)	35.5±3.20	29-39
Sediment temperature (°C)	33.13±2.54	28-37
Water depth (cm)	9.1±1.40	6.3-11.32
pH	6.39±0.18	6.11-6.7
Conductivity (μscm^{-1})	635.28±283.01	140.6-988.3
Dissolved oxygen (mgl^{-1})	9.88±2.65	5.41-15.20
Biological oxygen demand (mgl^{-1})	6.39±2.81	0.87-11.33
Total alkalinity (mgl^{-1})	12.51±2.69	8-18
Free carbon dioxide (mgl^{-1})	4.13±2.71	2-13.98
Nitrate-nitrogen (mgl^{-1})	1.56±0.97	0.51-3.8
Phosphate-phosphorous (mgl^{-1})	0.14±0.03	0.08-0.19
Silicate (mgl^{-1})	0.39±0.15	0.10-0.64
Chlorophyll-a (x 10^{-3} mg l^{-1})	0.48±0.31	0.05-1.06

mean±SD; n= 48

2.3. Laboratory analysis

Chemical properties viz., pH and conductivity of the water samples were recorded using pH meter (Systronics; model 103621) and conductivity meter (Systronics; model 308) respectively. Estimations of DO, BOD (for 3 days at 20°C), total alkalinity (TA), free carbon dioxide (CO_2), nitrate-nitrogen (nitrate-N), phosphate-phosphorous (phosphate-P), and chlorophyll-a were done following Trivedi and Goel (1984) and APHA (2012).

For qualitative and quantitative studies of plankton and rice-stem epiphytic communities, upto lowest taxonomic level using a binocular microscope (Olympus, Model B-2) at 10X and 40X magnifications following standard keys (Ward and Whipple, 1959; Needham and Needham, 1972; Biswas, 1980; Michael, 1984; Pentecost, 1984; Michael and Sharma, 1988; Santhanam *et al.*, 1989; Anand, 1989, 1998; Battish 1992; Tripathi and Pandey, 1995; Prasad and Singh, 1996;

Table 2: Distribution and taxonomic richness of phytoplankton in rice field water and phyto-epiphyton on rice stems in Asra rice fields during its aquatic phase.

Class /Taxa	Phytoplankton	Phyto-epiphyton
Class-Bacillariophyceae		
Achnanthes sp.	+	+
Amphora sp.	+	+
Cymbella sp.	+	+
Diatoma sp.1	+	+
Diatoma sp.2	+	-
Encyonema sp.	+	+
Epithemia sp.	+	+
Eunotia sp.1	+	+
Eunotia sp.2	+	-
Fragilaria sp.	+	+
Frustulia sp.	+	+
Gomphonema sp.	+	+
Hantzschia sp.	+	+
Melosira sp.	+	+
Meridion sp.	+	-
Navicula sp.1	+	+
Navicula sp.2	+	-
Navicula sp.3	+	-
Navicula sp.4	+	-
Navicula sp.5	+	+
Navicula sp.6	-	+
Nitzschia sp.1	+	-
Nitzschia sp.2	+	-
Nitzchia sp.3	+	+
Pinnularia sp.	+	+
Rhopalodia sp.	+	+
Stauroneis sp.	+	+
Surirella sp.	+	+
Synedra ulna	+	+
Tabellaria sp.	+	-
Total taxa: 30	**29**	**21**
Class-Chlorophyceae		
Ankistrodesmus sp.	+	+
Ankyra sp.	+	-
Asterococcus sp.	+	+
Chlamydomonas sp.	+	-
Chlorococcum sp.	+	+
Closterium sp.1	+	+
Closterium sp.2	+	+
Closterium sp.3	+	+
Closterium sp.5	+	-
Closterium sp.6	-	+
Cosmarium sp.1	+	-
Cosmariam sp.2	+	+
Cylindrocystis sp.	+	-
Desmidium sp.	+	+
Docidium sp.	+	+

Euastrum sp.	+	+
Geminella sp.	+	-
Gloeocystis sp.	+	-
Gonatozygon sp.	+	+
Microspora sp.	+	+
Mougeotia sp.	+	-
Oedogonium sp.	+	+
Pandorina sp.	+	-
Pediastrum sp.	+	+
Protococcus sp.	+	+
Scenedesmus sp.	+	+
Selenastrum sp.	+	-
Sphaerozosma sp.	+	+
Spirogyra sp.	+	+
Staurastrum sp.	+	+
Tetraedron sp.	+	-
Ulothrix sp.	+	+
Zygnema sp.	+	-
Total taxa: 33	**32**	**21**
Class-Cyanophyceae		
Anabaena sp.	+	+
Aphanizomenon sp.	-	+
Aphanocapsa sp.	+	+
Chroococcus sp.	+	-
Merismopedia sp.	+	-
Microcoleus sp.	+	+
Microcystis sp.	+	+
Nostoc sp.	+	-
Oscillatoria sp.	+	+
Phormidium sp.	+	+
Total taxa: 10	**9**	**7**
Class-Euglenophyceae		
Euglena sp.	+	+
Phacus sp.	+	+
Trachelomonas sp.	+	+
Total taxa: 3	**3**	**3**
Class-Xanthophyceae		
Tribonema sp.	+	+
Vaucheria sp.	+	-
Total taxa: 2	**2**	**1**
Class-Zygnemophyceae		
Micrasterias sp.	+	+
Triploceras sp.	+	+
Total taxa: 2	**2**	**2**
Grand total: Class-6; Taxa-80	**77**	**55**

'+' indicates presence and '-' indicate absence of the taxa concerned in the Asra rice fields during its aquatic phase

Table 3: Distribution and taxonomic richness of zooplankton in rice field water and zoo- epiphyton on rice stems in *Asra* rice fields during its aquatic phase.

Group /Taxa	Zooplankton	Zooepiphyton
Group-Protozoa		
Arcella sp.	+	+
Centropyxis sp.	+	+
Difflugia sp.	+	+
Euglypha sp.	+	-
Trinema sp.	+	-
Total taxa: 5	**5**	**3**
Group-Cladocera		
Alona sp.	+	-
Alonella sp.	+	-
Bosmina sp.	+	+
Chydorus sp.	+	+
Diaphanosoma sp.	+	-
Macrothrix sp.	+	-
Pleuroxus sp.	+	+
Simocephalus sp.	+	+
Total taxa: 8	**8**	**4**
Group-Copepoda		
Bryocamtus sp.	+	-
Cyclops sp.	+	-
Diaptomus sp.	+	-
Mesocyclops sp.	+	+
Total taxa: 4	**4**	**1**
Group-Ostracoda		
Cypris sp.	+	+
Total taxa: 1	**1**	**1**
Group-Rotifera		
Asplanchna sp.	+	+
Brachionus sp.	+	-
Keratella sp.	+	-
Lecane luna	+	+
Lepadella sp.	+	+
Monostyla sp.	+	+
Mytilina sp.	+	+
Notholca sp.	+	-
Polyarthra sp.	+	-
Testudinella sp.	+	-
Trichocerca sp.	+	-
Total taxa: 11	**11**	**5**
Grand total: Group-5;	**29**	**14**
Taxa-29		

'+' indicates presence and '-' indicate absence of the taxa concerned in the Asra rice fields during its aquatic phase.

Bilgrami and Saha, 2004; APHA, 2012). Quantitative analysis of both plankton and rice-stem epiphyton communities were done following Lackey's drop method (Lackey, 1938), and was expressed as number of individual litre^{-1} for planktonic organisms, and number of individual cm^{-2} for the rice-stem epiphytic organisms.

2.4. Statistical analysis

Canonical correspondence analyses (CCA) were done to determine the relationships of plankton and rice stem epiphyton with their habitat conditions in the rice field. All statistical analyses were done using PAST version 3.10 (Hammer *et al*., 2001).

3. Results

3.1. Asra rice cropping season

Two traditional varieties of paddy viz., *Kalakhura* and *Badal* are grown under *Asra* rice cropping season in the study area. These paddy varieties show the unique ability to grow rapidly by elongation of internodes with the rising water level. The local farmers generally directly broadcast the seeds of *Asra* rice cultivars to the low-lying areas near riparian region of river and in wetlands where the seedlings grow into a mature plant. During the entire rice cultivation period, the farmers do not apply any agro-chemicals in the rice fields. The rice fields remain under aquatic phase for 4 months.

3.2. Physico-chemical properties of the rice field water

The *Asra* rice fields during its aquatic phase behave like shallow aquatic systems with slightly acidic water pH, greater DO and moderate BOD and nutrients like NO_3-N and PO_4-P (Table 1).

3.3. Species composition, richness and abundance of plankton and rice stem epiphyton communities

Overall, 80 taxa of algae comprising both the free-floating (phytoplankton) and attached forms (rice-stem phyto-epiphyton) were found in the *Asra* rice fields (Table 2). Out of the total algal taxa, 77 taxa of phytoplankton were found in the rice field water and 55 taxa of phyto-epiphyton were found on the rice stems (Table 2). The richness pattern of phytoplankton taxa under different classes showed the following trend: Chlorophyceae (32 taxa)> Bacillariophyceae (29 taxa) > Cyanophyceae (9 taxa) > Euglenophyceae (3 taxa) > Xanthophyceae (2 taxa) = Zygnemophyceae (2 taxa). On the other hand, the richness pattern of rice stem phyto-epiphyton taxa under different classes depicted the following trend: Bacillariophyceae (21 taxa) = Chlorophyceae (21 taxa) > Cyanophyceae (7 taxa) > Euglenophyceae (3 taxa) > Zygnemophyceae (2 taxa) = Xanthophyceae (2 taxa) (Table 2).

Besides, amongst the animalcules, 29 taxa comprising both the suspended (zooplankton) and attached (rice-stem zoo-epiphyton) forms were found in the *Asra* rice fields (Table 3). Out of the total animalcule taxa, 29 taxa comprised of the suspended form i.e., zooplankton which were found in the rice field water and 14 taxa comprised of the attached forms i.e., zoo-epiphyton which were found on the rice stem (Table 3). The taxa richness pattern of zooplankton under different groups depicted the following trend: Rotifera (11 taxa) > Cladocera (8 taxa) > Protozoa (5 taxa) > Copepoda (4 taxa) > Ostracoda (1 taxon). The taxa richness pattern of different zoo-epiphyton under different groups registered the following trend: Rotifera (5 taxa) > Cladocera (4 taxa) > Protozoa (3 taxa) > Copepoda (1 taxon) = Ostracoda (1 taxon) (Table 3). Amongst the different phytoplankton classes abundance of Bacillariophyceae was highest followed by Chlorophyceae, Cyanophyceae, Zygnemophyceae, Euglenophyceae and Xan-

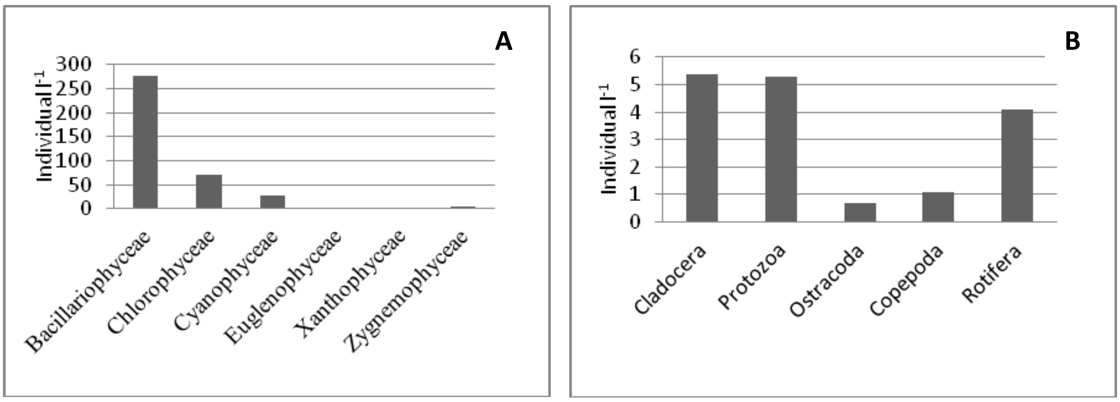

Fig. 2: Abundance of phytoplankton classes (A) and zooplankton groups (B) in the *Asra* rice fields during its aquatic phase.

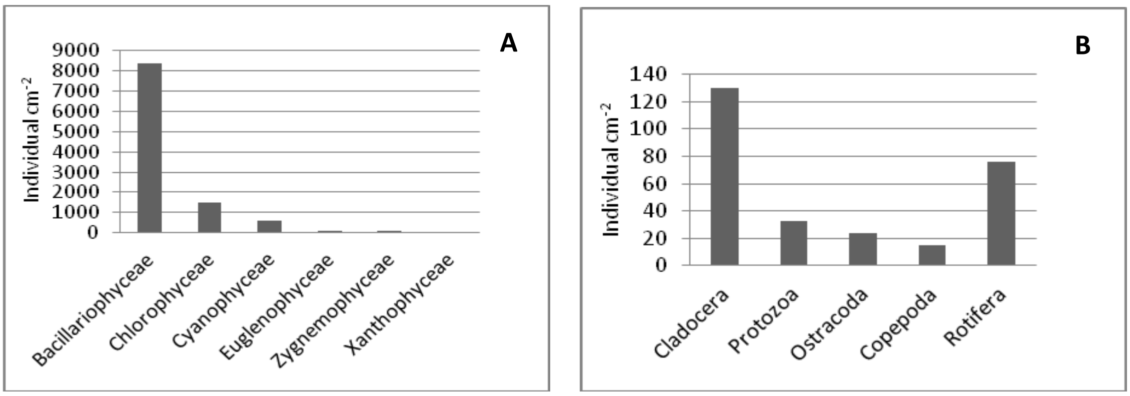

Fig. 3: Abundance of rice stem phyto-epiphyton classes (A) and rice stem zoo-epiphyton groups, (B) in the Asra rice fields during its aquatic phase.

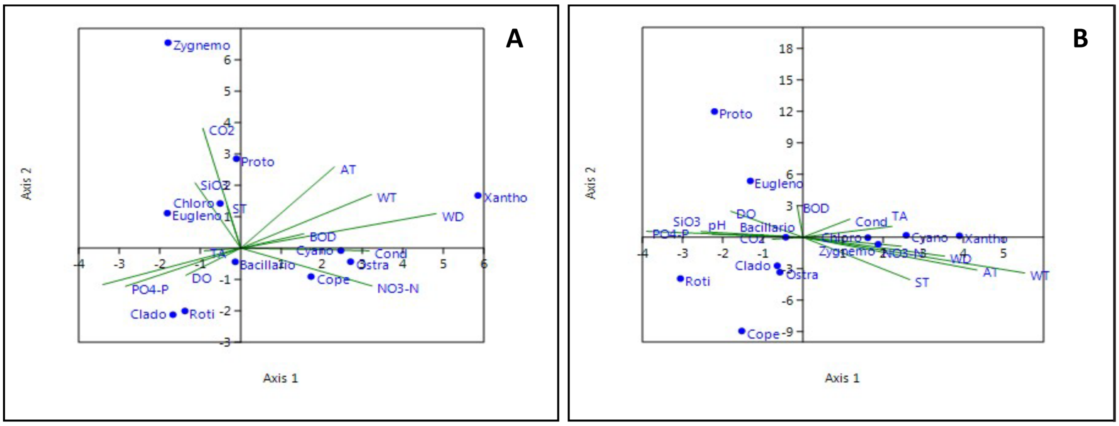

Fig. 4: Ordination plot for Canonical Correspondence Analysis of plankton (A) and rice stem epiphyton (B) communities in *Asra* rice fields during its aquatic phase. Environmental variables are represented by green lines and the taxonomic classes and groups of plankton and rice stem epiphyton are depicted by blue dots. The position of the class and group points indicates the environmental preference of the phytoplankton, rice stem phyto-epiphyton classes and zooplankton, rice stem zoo-epiphyton groups. AT-Air temperature; WT-Water temperature; ST-Sediment temperature WD-Water depth; Cond-Conductivity; DO-Dissolved oxygen; BOD-Biological oxygen demand; TA-Total alkalinity; CO_2-Free carbon dioxide. Bacil-Bacillariophyceae; Chloro-Chlorophyceae; Cyano-Cyanophyceae; Eugleno-Euglenophyceae; Zygnemo-Zygnemophyceae; Xantho-Xanthophyceae; Clado- Cladocera; Roti- Rotifera, Proto-Protozoa; Cope-Copepoda.

thophyceae (Fig. 2A) whereas amongst the different groups of zooplankton abundance of Cladocera was highest followed by Protozoa, Rotifera, Copepoda and Ostracoda (Fig. 2B). Amongst the different rice stem phyto-epiphyton classes abundance of Bacillariophyceae was highest followed by Chlorophyceae, Cyanophyceae, Zygnemophyceae, Euglenophyceae and Xanthophyceae (Fig. 3A) whereas amongst the different groups of rice stem zoo-epiphyton abundance of Cladocera was highest followed by Rotifera, Protozoa, Ostracoda and Copepoda (Fig. 3B).

3.4. Influence of physico-chemical parameters of the rice field water on plankton and rice stem epiphyton communities

The Canonical Correspondence Analysis of plankton and rice stem epiphyton communities in water-logged rice fields of *Asra* showed the relationships of different physico-chemical variables of the rice field water with planktonic communities (Fig. 4A) and rice stem epiphytic communities (Fig. 4B). The most influential environmental factor for phytoplankton classes like Chlorophyceae was SiO_3 and ST; and for zooplankton groups like Cladocera and Rotifera it was PO_4-P (Fig. 4A). In case of the rice stem epiphytic communities, the most influential environmental factor for the rice stem phyto-epiphyton belonging to class Bacillariophyceae was pH, PO_4-P, SiO_3, DO and CO_2. In case of Chlorophyceae, it was NO_3-N, WD, AT, WT and ST (Fig. 4B).

4. Discussion

4.1. Physico-chemical properties of rice field water

Physico-chemical properties of water in the *Asra* rice fields show that its water was slightly acidic with relatively greater DO and moderate BOD and nutrients like NO_3-N and PO_4-P. All the water quality parameters of the *Asra* rice fields were comparable with the standards for warm water fishery (Boyd, 1998; Halwart and Gupta, 2004). The WD is comparable with the standard as per Tamil Nadu Agricultural University, Coimbatore (Source: http://agritech.tnau.ac.in).

4.2. Species composition, richness and abundance of plankton and rice stem epiphyton communities

Chlorophyceae and Bacillariophyceae constituted the dominant classes of algae in the study area both as planktonic and rice stem epiphytic forms. Low water pH, moderate nutrient concentration, and high WT due to greater solar intensity favored the growth of Chlorophyceae (Halwart and Gupta, 2004; Zębek, 2004) in the selected rice fields. Our study showed greater association of Chlorophyceae with NO_3-N, WD, AT, WT and ST. Richness of Bacillariophyceae indicates the presence of greater quantities of available silica (Wetzel and Likens, 2000) in the rice field water. Our study showed greater association of Bacillariophyceae with pH, PO_4-P, SiO_3, DO and CO_2 of the rice field water. Distribution and taxonomic richness of Cyanophyceae was less. This might be attributed to the fact that Cyanophyceae are sensitive to high light intensities (Roger and Reynaud, 1982; Song *et al.*, 2005), acidic pH (Halwart and Gupta, 2004) and low phosphate-P conditions (Izaguirre *et al.*, 2004). All these factors together might have acted cumulatively which resulted into poor taxonomic richness of Cyanophyceae in the *Asra* rice field. Besides, representation of the taxonomic richness of algae belonging to classes Euglenophyceae, Zygnemophyceae and Xanthophyceae in the *Asra* rice fields were very less thereby indicating unfavorable habitat condition for these phytoplankton classes in the *Asra* rice fields.

In case of rice stem phyto-epiphytic communities dominance of Bacillariophyceae in the *Asra* system indicates greater availability of silica in the rice field environment (Lukaw *et al.*, 2012). In addition, the rice plants are very good silicon accumulator, which serves as favorable substrate for Bacillariophyceae to grow and proliferate on it (Yamaji and Feng, 2007). Hence, Bacillariophyceae have greater preference to remain attached on any substratum, which was available in the rice field in the form of rice stems (van Dam *et al.*, 2002). Bere (2010) has also reported preference of Bacillariophyceae to exhibit periphytic life on organic substrates over planktonic life.

Among zooplankton and zoo-epiphyton, taxonomic richness of both Rotifera and Cladocera was greater. This might be attributed to greater food availability for these two groups of animalcules in the form of organic matter. Greater variation in physico-chemical parameters due to seasonal influence, change in growth stage of rice plant resulting in different texture and organic composition as substrate might have contributed to variation in taxonomic richness of rice stem zoo-epiphyton. Favorable environmental factors in terms of greater organic matter contents as feeding materials for the rotifers and some of their physiological specialization viz., less specialized feeding, parthenogenetic reproduction and high fecundity also favored greater richness of the rotiferan group (Sampaio *et al*., 2002) on rice stems of the *Asra* rice fields. However, when compared taxonomic richness of both zooplankton and rice stem zoo-epiphyton were very less in comparison to phytoplankton and phyto-epiphyton taxa. High WT, low water pH and rapid fluctuation of different water parameters may be attributed to be the main factors responsible for less richness of zooplankton and zoo-epiphyton communities in the water logged rice fields. It is also observed that rice stems in wet rice fields act as suitable substrate for colonization of attached algae as compared to attached animalcules, which may be attributed to the shift from wet to dry environment in rice field ecosystem due to the variations in the seasonal rainfall pattern. This probably favored only those organisms that have appropriate survival and reproduction strategies through dormancy and production of resistant eggs that remain deposited on the sediment during the fallow period and are very tolerant to extreme environmental conditions (Nandini and Sarma, 2007).

There was also compositional similarity between plankton and rice stem epiphyton communities in the *Asra* rice fields. Compositional similarity of planktonic and rice stem epiphytic taxa might be due to the fact that some planktonic life forms change and adopt to epiphytic mode of life and vice-versa depending on their requirement in terms of availability of various resources like sunlight, nutrients etc. However, when compared taxonomic richness of plankton in the rice field water was more in comparison to that of rice stem epiphyton. All these indicate that *Asra* rice fields are more favorable for the diverse planktonic life forms, which prefer to remain suspended in the rice field water.

Amongst the phytoplankton classes (Fig. 2A) abundance of Bacillariophyceae is highest which indicates availability of greater quantities of silica (Wetzel and Likens, 2000) in *Asra* rice fields. The next dominant phytoplankton class was Chlorophyceae, which may be attributed to slightly acidic water, high water temperature, and moderate nutrients in the *Asra* rice field water. Among zooplankton (Fig. 2B) abundance of Cladocera was highest. This indicates presence of greater quantities of organic matters together with the phytoplankton and the bacteria, which all together constituted the food for the cladocerans (Wetzel, 2001).

Amongst the rice stem phyto-epiphyton classes (Fig. 3A) abundance of Bacillariophyceae was highest which again indicates availability of greater quantities of silica in the *Asra* rice fields. The next dominant phyto-epiphyton class was Chlorophyceae, which may be attributed to low water pH, high WT, and moderate nutrients like nitrate-N and phosphate-P within the system. In case of rice stem zoo-epiphyton (Fig. 3B), abundance of Cladocera was highest followed by Rotifera indicating presence of greater quantities food materials for both the cladocerans and rotifers in the form of organic matters.

4.3. Influence of physico-chemical parameters of the rice field water on plankton and rice stem epiphyton communities

Physico-chemical parameters of the rice field water influenced the plankton and rice stem epiphyton communities differentially in the *Asra* rice fields. The study showed that the plankton and rice stem epiphyton are largely influenced by interaction with a number of physico-chemical variables existing in the rice field water like WT, pH, DO, nitrate-N, and phosphate-P etc. It may be mentioned here that like any aquatic system, the existing habitat condition in the water logged rice fields of *Asra* plays an important role in the distribution, diversity and growth of phytoplankton/phyto-epiphyton, on which zooplankton/zoo-epiphyton and higher consumers depend for their survival.

The present study, therefore, revealed the complex interactions of diverse plankton communities in rice field water and epiphyton communities on the rice stem in the *Asra* rice fields. The existing environmental condition under *Asra* showed greater suitability for algae-both the planktonic and the epiphytic forms belonging to classes Bacillariophyceae and Chlorophyceae and the animalcules comprising the planktonic and the epiphytic forms belonging to groups Cladocera and Rotifera. It may be mentioned here that diatoms belonging to class Bacillariophyceae are highly nutritious as fish food (Ramachandran *et al*., 2017) and green algae belonging to class Chlorophyceae act as fish food in aquaculture systems for increased fish production (Hasan and Chakrabarti, 2009). In addition, both rotifers and cladocerans are the most nutritive group of zooplankton, which enhances fish growth (Lubzens *et al*., 1989; Ferdous and Muktadir, 2009). Most of the fish in nature feed on live food such as plankton and rice-stem epiphyton, which altogether constitute the most valuable food resource for aquaculture (Das *et al*., 2012). Live food organisms contain all the nutrients and hence act as living capsules of nutrition (Das *et al*., 2012) for fishes. Water logged *Asra* rice fields with high abundance of live food for fish indicate suitability of the system for integrated rice fish farming.

5. Conclusion

The present study reveals that the *Asra* rice fields are rich repository of planktonic and rice stem epiphytic communities, the natural live food resources for fish. Water retention time within such rice fields is for four months. Further, analyses of water quality parameters in the *Asra* rice fields revealed that the water properties of *Asra* rice fields are suitable for concurrent rice-fish culture. As Barak Valley often faces the ecological problem of unpredictable heavy rainfall and the associated incidence of flood, which results in frequent submergence of low-lying agricultural area, there should be initiation of some community resilient mechanism amongst the local farmers to mitigate the recurrent flood problem in this region in context of their livelihood sustenance. In this regard, the present study emphasizes on conservation of traditional practice of rice farming system like *Asra*, and highlights the need for sustainable utilization of the existing bioresources in such system by introducing the concurrent practice of rice-fish culture.

Acknowledgements

The authors are thankful to all the respondent farmers who have contributed to the information related to the study. The first author is thankful to University Grants Commission, New Delhi for partial financial support to carry out the present work. The authors are also thankful to anonymous reviewers for their valuable suggestion for further improving the manuscript.

References

Anand, N. 1989. *Hand book of blue-green algae (of rice fields of South India)*. Bishen Singh Mahendra Pal Singh, Dehra Dun, India, pp. 79.

Anand, N. 1998. *Indian freshwater microalgae*. Bishen Singh Mahendra Pal Singh, Dehra Dun, India, pp. 94.

APHA, 2012. *Standard methods for examination of water and wastewater*. 22nd Edition. American Public Health Association, New York, pp. 1496.

Banerjee, S. 2013. Study of performance of indigenous paddy varieties under System of Rice Intensification (SRI) and conventional growing practices. National Consortium of SRI (NCS), New Delhi, pp. 35.

Battish, S. K. 1992. *Freshwater zooplankton of India*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, India, pp. 233.

Bere, T. 2010. Benthic diatom community structure and habitat preferences along an urban pollution gradient in the Monjolinho River, São Carlos, SP, Brazil. *Acta Limnologica Brasiliensia* **22**(1):80-92.

Berkes, F. 2004. Traditional Ecological Knowledge in perspective. In: J.T. Inglis, editor. *Traditional Ecological Knowledge: Concepts and Cases*. International Program on Traditional Ecological Knowledge, Ottawa, Canada, pp. 1-6.

Berkes, F. and Davidson-Hunt, I. 2006. Biodiversity, traditional management systems, and cultural landscapes: Examples from the boreal forest of Canada. *International Social Science Journal* **58**:35-47.

Bilgrami, K.S. and Saha, L.C. 2004. *A Text Book of Algae*. CBS Publishers and Distributors, New Delhi, pp. 263.

Biswas, K. 1980. *Common fresh and brackish water algal flora of India and Burma*. Botanical Survey of India, vol. XV. Periodical Experts Book Agency, India, pp. 105.

Boafo, Y.A., Saito, O., Kato, S., Kamiyama, C., Takeuchi, K. and Nakahara, M. 2016. The role of traditional ecological knowledge in ecosystem services management: the case of four rural communities in Northern Ghana. *International Journal of Biodiversity Science, Ecosystem Services and Management* **12**(1-2):24-38.

Boyd, C.E. 1998. *Water quality for pond aquaculture, Research and Development Series* No. 43. International Center for Aquaculture and Aquatic Environments, Alabama Agricultural Experiment Station, Auburn University, Alabama, pp. 482.

Brodt, S.B. 2001. A Systems Perspective on the Conservation and Erosion of Indigenous Agricultural Knowledge in Central India. *Human Ecology* **29**:99-120.

Ceuterick, M., Vandebroek, I. and Pieroni, A. 2011. Resilience of Andean urban ethnobotanies: A comparison of medicinal plant use among Bolivian and Peruvian migrants in the United Kingdom and in their countries of origin. *Journal of Ethnopharmacology* **136**:27-54.

Das, P., Mandal, S. C., Bhagabati, S. K., Akhtar, M. S. and Singh, S. K. 2012. Important Live Food Organisms and Their Role in Aquaculture. In: Sundaray, J.K., Sukham, M., Mohanty, R.K. Otta, S. K. (Eds.) *Frontiers in Aquaculture*, Narendra Publishing House, New Delhi, pp. 69-86.

Das, T. and Das, A. K. 2006. Managing rice biodiversity by smallholder farmers: A case study in Barak Valley, Assam. *Indian Journal of Plant Genetic Resources* **19**:12-18.

District Irrigation Plan, 2016-2021, Karimganj, NABARD Consultancy Private Limited, New Delhi. Available at Assamhttp://dirhorti.assam.gov.in/sites/default/files/swf_utility_folder/departments/horticulture_medhassu_in_oid_5/menu/document/District%20Irrigation%20Plan%2C%20Karimganj_0.pdf. Accessed on 27. 11. 2017.

Dutta Deka, S., Sarmah, B. and Sharma, S. 2014. Conservation and Utilization of Indigenous Rice Varieties for a Sustainable Livelihood Security. *International Journal of Environmental Research and Development* **4**:291-296.

Ferdous, Z. and Muktadir, A.K.M. 2009. A Review: potentiality of zooplankton as bioindicator. *American Journal of Applied Sciences* **6**(10):1815-1819.

Folke, C. 2004. Traditional knowledge in social-ecological systems. *Ecology and Society* **9**(3):7.

Friis-Hansen, E. 1996. The role of local plant genetic resource management in participatory breeding. In: Eyzaguire, P.B. and Iwanaga, M. (Eds.) *Participatory Plant Breeding,* Rome, IPGRI, pp. 66-76.

Gadgil, M., Berkes, F. and Folke, C. 1993. Indigenous knowledge for biodiversity conservation. *Ambio* **22**:151-156.

Godoy, R., Reyes-García, V., Byron, E., Leonard, W. and Vadez, V. 2005. The effect of market economies on the well-being of indigenous peoples and on their use of renewable natural resources. *Annual Review of Anthropology* **34**:121-138.

Gómez-Baggethun, E. 2009. Perspectivas del conocimiento ecológico local ante el proceso de globalización. *Papeles de Relaciones Ecosocialesy Cambio Global* **107**:57-67.

Gómez-Baggethun, E., Mingorría, S., Reyes-García, V., Calvet, L. and Montes, C. 2010. Traditional ecological knowledge trends in the transition to a market economy: Empirical study in Doñana natural areas. *Conservation Biology* **24**:721-729.

Gómez-Baggethun, E., Reyes-García, V., Olsson, P. and Montes, C. 2012. Traditional ecological knowledge and community resilience to environmental extremes. A case study in Doñana, SW Spain. *Global Environmental Change* **22**:640-650.

Gray, C.L., Bilsborrow, R.E., Bremner, J.L. and Lu, F. 2008. Indigenous land use in the Ecuadorian Amazon: a cross-cultural and multilevel analysis. *Human Ecology* **36**:97-109.

Halwart, M. and Gupta, M.V. (Eds.) 2004. *Culture of Fish in Rice Fields*. FAO and the World Fish Center, pp. 83.

Hammer, Ø., Harper, D.A.T. and Ryan, P.D. 2001. PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* **4**(1):9.

Hasan, M. R. and Chakrabarti, R. 2009. *Use of algae and aquatic macrophytes as feed in small-scale aquaculture: a review*. FAO Fisheries and Aquaculture Technical Paper No. 531. Rome, FAO, pp. 123.

http://agritech.tnau.ac.in/fishery/fish_ifs_agri.html accessed on 22.03.2018.

Izaguirre, I., Farrell, I.O., Unrein, F., Afonso, M. and Tell, G. 2004. Algal assemblages across a wetland, from a shallow lake to relictual oxbow lakes (Lower Parana River, South America). *Hydrobiologia* **511**:25-36.

Kingsbury, N.D. 2001. Impacts of land use and cultural change in a fragile environment: indigenous acculturation and deforestation in Kavanayen, Gran Sabana, Venezuela. *Interciencia* **26**:327-336.

Lackey, J.B. 1938. The manipulation and counting of river plankton and changes in some organisms due to formalin preservation. *Public Health Reports* **53**:2080-2093.

Lubzens, E., Tandler, A. and Minkoff, G. 1989. Rotifers as food in aquaculture. *Hydrobiologia* **186**(1):387-400.

Lukaw, Y.S., Ladu, J.L.C. and Kenyi, D.D. 2012. Seasonal influence of physicochemical variables on phytoplankton abundance in Jebel Aulia Reservoir in Khartoum, Sudan. *Nature and Science* **10**(11):168-175.

McCarter, J. and Gavin, M.C. 2011. Perceptions of the value of traditional ecological knowledge to formal school curricula: opportunities and challenges from Malekula Island, Vanuatu. *Journal of Ethnobiology and Ethnomedicine* **7**(1):38.

McDade, T., Reyes-García, V., Leonard, W., Tanner, S. and Huanca, T. 2007. Maternal ethnobotanical knowledge is associated with multiple measures of child health in the Bolivian Amazon. *Proceedings of the National Academy of Sciences* **104**:6134-6139.

Michael, P. 1984. *Ecological Methods for Field and Laboratory investigations*. Tata McGraw Hill Publishing Company Limited, New Delhi, pp. 404.

Michael, R.G. and Sharma, B.K. 1988. *Indian Cladocera (Crustacea: Branchiopoda: Cladocera). Fauna of India and adjacent countries series*. Zoological Survey of India, Calcutta, pp. 262.

Nandini, S. and Sarma, S.S.S. 2007. Effect of algal and animal diets on life history of the freshwater copepod *Eucyclops serrulatus* (Fisher, 1851). *Aquatic Ecology* **41**:75-74.

Needham, J.G. and Needham, P.R. 1972. *A Guide to the Study of Freshwater Biology*, 5th Edn. Holden-Day Inc. San Francisco, California, pp. 108.

Pentecost, A. 1984. *Introduction to freshwater algae*. Richmond Publishing Corporation, England, pp. 247.

Prasad, B.N. and Singh, Y. 1996. *Algal indicators of water pollution*. Bishen Singh Mahendra Pal Singh, Dehra Dun, India, pp. 440.

Ramachandran, K., Thamizharasan and Sankari 2017. Efficacy of diatomixtm in generation of live feed diatoms in commercial aquaculture ponds. *International Journal of Recent Scientific Research* **8**(12):22435-22441.

Reid, W.V., Berkes, F., Wilbanks, T. and Capistriano, D. 2006. *Bridging scales and local knowledge in assessments*. Island Press; Washington, D.C., USA, pp. 351.

Reyes-García, V. 2013. Introduction to Special Section: On the relations between schooling and local knowledge. Guest Editorial. *Learning and Individual Differences* **27**:201-205.

Reyes-García, V., Mcdade, T., Vadez, V., Huanca, T., Leonard, W.R., Tanner, S. and Godoy, R. 2008. Non-market returns to traditional human capital: Nutritional status and traditional knowledge in a native Amazonian society. *Journal of Development Studies* **44**:217-232.

Roger, P.A. and Reynaud, P.A. 1982. Free Living Blue Green Algae in Tropical Soils. In: Dommer-Gues, Y. and Diem, H. (Eds.) *Microbiology of Tropical Soils and Plant Productivity*, Martinus Nijhoff Publisher, La Hague, pp. 147-168.

Sampaio, E.V., Rocha, O., Matsumura-Tundisi, T. and Tundisi, J.G. 2002. Composition and abundance of Zooplankton in the limnetic zone of seven reservoirs of the Paranapanema River, Brazil. *Brazilian Journal of Biology* **62**:525-545.

Santhanam, R. Velayutham, P. and Jegatheesan, G. 1989. *A Manual of Freshwater Ecology (An Aspect of Fishery Environment)*. Daya Publishing House, Delhi, pp. 134.

Saxena, S. and Singh, A.K. 2006. Revisits to definitions and need for inventorization or registration of landrace, folk, farmers' and traditional varieties. *Current Science* **91**(11):1451-1454.

Sebby, K. 2010. *The Green Revolution of the 1960's and Its Impact on Small Farmers in India* Environmental Studies Undergraduate Student Theses. 10. http://digitalcommons.unl.edu/envstudtheses/10

Song, T., Martensson, L., Eriksson, T., Zheng, W.W. and Rasmussen, U. 2005. Biodiversity and seasonal variation of the cyanobacterial assemblage in a rice paddy field in Fujian, China. *FEMS Microbiology Ecology* **54**:131-140.

Subudhi, H.N., Samantaray, S., Swain, D. and Singh, O.N. 2012. Collection and agro-morphological characterization of aromatic short grain rice in eastern India. *African Journal of Agricultural Research* **7**(36):5060-5068.

Tang, C.P. and Tang, S.Y. 2010. Institutional adaptation and community-based conservation of natural resources: The cases of the Tao and Atayal in Taiwan. *Human Ecology* **38**:101-111.

Toledo, V. 2002. Ethnoecology: *A conceptual framework for the study of indigenous knowledge of nature. Ethnobiology and Biocultural Diversity*. International Society of Ethnobiology, Georgia, USA, pp. 522.

Tripathi, A.K. and Pandey, S.N. 1995. *Water pollution*. Ashish Publishing House, New Delhi, India, pp. 326.

Trivedi, R.K. and Goel, P.K. 1984. *Chemical and biological methods for water pollution studies*. Environment Publication, Karad, India, pp. 250.

Turner, N.J. and Turner, K. 2008. Where our women used to get the food: Cumulative effects and loss of ethnobotanical knowledge and practice; case study from coastal British Columbia. *Botany* **86**:103-115.

Van Dam, A.A., Beveridge, M.C.M., Azim, M.E., Verdegem, M.C.J. 2002. The potential of fish production based on periphyton. *Review of Fish Biology and Fisheries* **12**:1-31.

Ward, J.V. and Whipple, G.C. 1959. *Fresh water Biology*, 2nd edn. Wiley, New York, pp. 1248.

Wetzel, R.G. 2001. *Limnology: Lake and River Ecosystems*. Elsevier Press, New York, pp. 1023.

Wetzel, R.G. and Likens, G. 2000. *Limnological Analysis*, 3rd edn. Springer Publications, New York, pp. 429.

Yamaji, N. and Feng, M.J. 2007. Spatial distribution and temporal variation of the rice silicon transporter Lsi1. *Plant Physiology* **143**(3):1306-1313.

Zębek, E. 2004. Species biodiversity of net phytoplankton as an indicator of trophic changes in the urban lake Jeziorak Mały. *TEKA Commission of Protection and Formation of Natural Environment* **1**:316-321.