Eco. Env. & Cons. 26 (1) : 2020; pp. (125-134)
Copyright@ EM International
ISSN 0971–765X

Limnological assessment of Tasek lake – a Tectonic lake of Garo Hills, Meghalaya, India and its impact on livelihood development

Arup Kumar Hazarika[1] and Unmilan Kalita[2]

[1]Department of Zoology, Cotton University, Guwahati, India
[2]Department of Economics, Gauhati University, Guwahati, India

(Received 3 August, 2019; accepted 7 September, 2019)

ABSTRACT

Most of the Limnological studies are carried out on freshwater pond ecosystem. A least attention was made to cover tectonic lake. As such, the present study covered the limnological investigation in relation to plankton and fishes of Tasek Lake of East Garo Hills, Meghalaya (India) which was undertaken in the year 2018. Moreover, the study was done keeping in mind the economic significance of the lake vis-à-vis prospects of aquaculture. Water samples were randomly collected throughout the year (January to December) to find out monthly variation in physico-chemical parameters and abundance of plankton of Tasek Lake, and brief interactions were made with local villagers regarding its economic prospects. The limnological investigation revealed that the abundance of plankton population was minimum of 1027 u/l in the month of May to 5377u/l in the month of January . A total of 43 species of fishes belong to 8 orders and 12 families have been identified during the study period. A distinct relationship with monthly variation in physic-chemical parameters and plankton as well as positivity in fish farming prospects has been well observed as part of this study.

Key word : *Physico-chemical, Plankton, Correlation coefficient, Fishgenetic resources.*

Introduction

The importance of physico-chemical parameters and plankton of water bodies has great concern in the field of Fishery science. A number of hydrological studies conducted in small water bodies of Northwest India (Das and Srivastava, 1956; Philipose, 1960; George, 1961a, b). A few studies have also been conducted in Northeast India covering hydrobiological work of fresh water ecosystem (Dey, 1979, 1981; Das, 1980; Sen, 1982; Lahon, 1982 Goswami, 1985; Dutta *et al.,* 1993; Hazarika and Dutta, 1994). However, a little attention has been made to study the limnology of the Tectonic Lake (Kar, 1984; Goswami, 1985). Moreover, the economic prospects have went observed in terms of Tasek lake. No literature has been found that has delved upon the lake's potential in aquaculture or fish farming. An abundance of fish consuming people in Meghalaya and its huge internal demand makes it all the more important to explore how its indigenous lakes can be converted into fisheries and be sustainably put into use. Hence, the present paper is aimed to cover a physico-chemical analysis of the Tasek lake of East Garo Hills, Meghalaya (India) in relation to plankton and fish, which has been neglected so far. The present study also envisages to do a brief discussion on the fishery prospect of Meghalaya, in general, and Tasek lake, in particular, as the lake is found to be important from the fishery

***Corresponding author's email:** cheifeditorclarion@gmail.com

point of view because of its linkage with different streams of Garo Hills.

Materials and Methods

The Tasek lake is a natural lake (90^{0}11′ East, 25^{0}34′ North; altitude- 600MSL) covering water surface area of 11.66 Ha. It is located at about 131 kms from Tura, the district head quarter of West Garo Hills. It is specifically located in East Garo Hills district, and about 32 kms. From the district headquarter, i.e. William Nagar. The site at which it is located is known as Rongre.

The Tasek Lake was supposed to be a hillock but due to the activities of the great earthquake on 12th of June 1897, the hill settled down and formed the lake. That is why the Shorearobasta (Sal trees) are still visible in the middle portion of the Lake.

The northern side of the lake is covered by thick dense forest; the southern side is covered by a hillock, in which the Tasek forests range, and guesthouse are located. In the eastern side of the lake, another small water body is located, which is known as Chitmarang Lake. This water body is located is connected with Tasek Lake by a narrow stream.

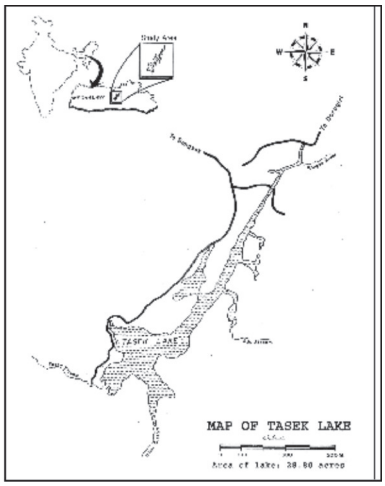

Fig. 1. Map of Tasek Lake

For analysis of the physico-chemical parameters of Tasek Lake, the sample for water analysis were randomly taken throughout the year 2001 (January to December) and mostly from well mixed zone. Physico-chemical parameters were investigated following the standard methods of Trivedy and Goel (1986) and APHA (1989). Regarding the plankton, samples were collected during the specific time of the day specially, during early hours through plankton net of bolting silk (No. 20).

During the study period, frequent netting was done by cast net to collect fishes, but where netting was not convenient due to presence of heavy stones or tree trunks in Tasek Lake, fishes were collected with the help of local people with their indigenous method. After collection, fishes were preserved in 4% formalin.

As far as the statistical interpretations are concerned 15 parameters were investigated in the present Tasek lake site covering all the months of the year, i.e. 2018. Correlation analysis has been done to investigate relationship among the different water quality parameters by using by the Karl person's coefficient of correlation.

$r = S (xy)/N\ dx\ dy$

where,

$x = (x – x)$; $y\ (y – y)$

r = Coefficient of correlation

dx = Standard deviation of x series

dy = Standard deviation of y series

N = Number of pairs of observation.

x y = Two different parameters.

The parameters of the regression on model were estimated by ordinary least square method. The regression on model is of the form:

$Y = b_0 + b_1 X_1 + b_2 X_2 + \ldots\ldots + b_n Xn + \hat{I}$

where,

$b, b_1, \ldots, b_n$ = constants to be determined.

Y = Plankton abundance (UL–1)

$X_1, \ldots\ldots, X_{15}$ are the different physico-chemical parameters and Î, is the error component.

As far as the statistical interpretations are concerned, 15 parameters were investigated in the present site. Correlation analysis has been done to investigate relationship among the different water quality parameters by using the Karl Pearson's coefficient of correlation (Table 3).

Owing to the beauty of Meghalaya and its incredible tourist potential, there have been concerted efforts to convert the Tasek lake into a tourist recreational spot as well as for fishery development activities under the Government of Meghalaya. The present study undertook an effort to ascertain whether the Tasek lake would be economically valuable as a fishery and whether it would have an impact on the livelihood of fringe dwellers. The methodology included brief discussions with the villagers during the limnological study along with

an analysis of secondary data, that was collected from government sources. Given the dearth of available information and the limited scope of our study, the analysis of the lake's economic importance was kept limited to its value as a fishery. It must be noted that tourism is another important aspect that needs careful examination as a means of livelihood and area development. However, it can be expected that developing the lake as a fishery while also popularizing it as a tourism destination would result in policy inconsonance.

Results

As part of the limnological investigation, a monthly variation in physico-chemical parameters and the abundance of plankton and fishes are given as follows:

Physico-Chemical Parameters

A distinct monthly variation in physico-chemical parameters have been observed in Tasek lake (Table 2). Water temperature varies from 19.20^0 C to 30.5^0 C throughout the year. The pH value ranges from 5.00 to 6.70 which indicates that water is quite alkaline in all months of the year. The conductivity of Tasek lake ranged from 17.50 μhos to 24.00μhos confirming its water to be quite soft. The transparency of Tasek lake ranged from 60.00 cm to 88.00 cm and its values were low in January, February and March. Hardness exhibited a good variation ranging from 50.0 mg/L to 80.0 mg/L. T—-he chloride content ranged between 6.75 mg/L to 15.00 mg/L. Duringmonsoon, the chloride level registered a slight increase. A moderate level of Free CO_2 was found which ranged between 0.45 mg/L to 2.50 mg/L. Dissolved oxygen was found to range from 6.20 mg/L to 12.35 mg/L while Biological Oxygen Demand (BOD) ranged from 2.00 to 3.10 mg/L. Chemical Oxygen Demand (COD) had values spanning from 16.50 mg/L to 30.25 mg/L.

Plankton abundance

The total average monthly plankton population was observed to be 3531 u/L (Table 1). The monthly abundance of plankton population in the present investigated site found to range from minimum of 1027 u/l in the month of May to 5377 u/l in the month of January. In general, there was a fluctuating trend in the month of July, August and September with little ups and downs. There was a sharp decline in May from which again rose in June. The maxima was reached in the month of January. The plankton species which were encountered during the course of investigation is given below:

Phytoplankton

A. **MYXOPHYCEAE**

1. *Anabaena* 2. *Aphanocapsa* 3. *Coelosphaerium*
4. *Merismopedia* 5. *Microcystis* 6. *Oscillatoria*
7. *Rivularia* 8. *Stigonema*

B. **CHLOROPHYCEAE**

1. *Actinastrum* 2. *Ankistrodesmus* 3. *Botryoccoccus*
4. *Bumellaria* 5. *Chlamydomonas* 6. *Closterium*
7. *Coelastrum* 8. *Chodatella* 9. *Dinobryon*
10. *Hormidium* 11. *Mugeotia* 12. *Oedogonium*
13. *Pediastrum* 24. *Scenedesmus*

C. **CYANOPHYCEAE**

1 *Arthropira* 2. *Anacystis* 3. *Gloecocapsa*
4. *Lyngbya* 5. *Spirulina* 6. *Phormidium*

D. **BACILLARIOPHYCEAE**

1. *Amphora* 2. *Asterionella* 3. *Cyclotella*
4. *Diatoma* 5. *Diatomella* 6. *Frustulia*
7. *Gyrosigma* 8. *Melosira* 9. *Meridion*
10. *Nitzschia* 11. *Orthosira* 12. *Synedra*.

E. **DINOPHYCEAE**: 1.*Ceratium*

F. **EUGLENINEAE**:

1. *Euglena* 2.*Lepocinclis* 3.*Phacus*

G. CHRYSOPHYCEAE:

1. *Mallomonas* 2. Synura

H. DESMIDACEAE

1.*Cosmarium* 2.*Desmidium* 3. *Euastrum*
4. *Netrium* 5.*Penium* 6.*Tetradesmus*

I. **DIATOMACEAE**:

1. *Amphora* 2.*Asterias* 3.*Coccneis*
4.*Cymbella* 5.*Fragilaria* 6.*Gomphonema*
7.*Gyrosigma*

Zooplankton

A. **ROTIFERS:**

1. *Asplancha* 2. *Brachionus* 3. *Filinia*
4. *Keratella* 5. *Lecane* 6. *Polyarthra*
7. *Schizocera* 8. *Teramastix* 9. *Trichocera*

B. **CLADOCERA:**

1. *Bosmina* 2. *Ceriodaphnia* 3. *Daphnia*
4. *Diaphnosoma* 5. *Moina*

C. **COPEPODA:**

1. *Alonella* 2. *Canthocampus* 3.*Cyclops*
4. *Diaptomus* 5.*Nauplius*

D. **OSTRACODA**: 1.*Cypris*

Fish Genetic Resources

A total of 43 species of fishes belonging to 8 orders and 12 families have been identified during the study period. Among these 4 species of fishes has commercial value namely *Labeorohita*, *Notopteruschitala*, *C. mrigala*, etc. A detailed and systematic list of the identified fish species are enumerated below:

Grade: Pisces
Class: Osteichthyes
Sub-class: Actinopterygii
a) Order: **CLUPEIFORMES**
Family **Clupeidae**
1) *Gudusiachapra* *(Hamilton)
b) Order: **OSTEOGLOSSIFORMES**
Family **Notopteridae**
2) *Notopteruschitala* * (Hamilton)
c) Order: **CYPRINIFORMES**
Family **Cyprinidae**
i) Sub-family **Abramidinae**
3) *Oxygastergora* (Hamilton)
4) *Salmostomabacaila* (Hamilton)
ii) Sub-Family **Rasborinae**
5) *Bariliusbarna* (Hamilton)
6) *Bariliusbendelisis* (Hamilton)
7) *Bariliusbarila* (Hamilton)
8) *Bariliusbola* (Hamilton)
9) *Danio (Danio) aequipinnatus* (McClelland)
10) *Danio (Danio) devario* (Hamilton)
11) *Danio (Brachydanio) rerio* (Hamilton)
12) *Esomusdanricus* (Hamilton)
13) *Rasbora elanga* (Hamilton)
iii) Sub-Family **Cyprininae**
14) *Accrossocheiliushexagonolepis* (McClelland)
15) *Chaguniuschagunio* (Hamilton)
16) *Cirrhinamrigala* (Hamilton)
17) *Cirrhinareba* (Hamilton)
18) *Crossocheiluslatiuslatius* (Hamilton)
19) *Garranasuta* (McClelland)
20) *Garagotylagotyla* (Gray)
21) *Labeoboga* (Hamilton)
22) *Labeocalbasu* (Hamilton)
23) *Labeodero* ** (Hamilton)
24) *Labeopangusia* (Hamilton)
25) *Labeorohita* (Hamilton)
26)*Osteobramacotiocotio* (Hamilton)
27)*Puntiuschola* (Hamilton)
28)*Puntiusclavatus* (McClelland)
29)*Tor tor* * (Hamilton)
30)*Tor putitora* ** (Hamilton)
Family **Psilorhynchidae**
31) *Psilorhynchusbalitora* **(Hamilton)
Family **Cobitidae**
32) *Botiadario* (Hamilton)
33) *Botiarostrata* (Gunther)
d) Order: **SILURIFORMES**
Family **Bagridae**
34)*Aorichthysseenghala* (Hamilton)
35)*Mystuscavasius* (Hamilton)
Family **Amblycipitidae**
36) *Amblycepsmangois* (Hamilton)
e) Order: **CHANNIFORMES**
Family **Channidae**
37) *Channaorientalis* (Hamilton)
38) *Channapunctata* (Bloch)
39) *Channastewartii* (Playfair)
f) Order: **PERCIFORMES**
Family **Chandidae**
40) *Chanda ranga* (Hamilton)
Family **Mugilidae**
41) *Sicamugilcascasia* (Hamilton)
g) Order: **MASTACEMBELIFORMES**
Family **Mastacembelidae**
42)*Mastacembelusarmatusarmatus** (Lacepede)
h) Order: **TETRAODONTIFORMES**
Family **Tetraodontidae**
43)*Tetraodon cutcutia* (Hamilton)

Economic significance of Tasek Lake

During the field study, it was observed that an ecolodge had been set up by the government's tourism development department (in 2016) and a few information boards had been put up describing the ecological and geological significance of the site. Interestingly, the site was supposed to be built up as a fishery development centre, although no substantial evidence was witnessed, apart from local fish-catching. Aquaculture has immense potential in upgrading the livelihood of dwellers of a particular region, which had also been acknowledged in the Meghalaya State Aquaculture Mission (2012-2017) document. The people of Meghalaya are primarily fish consumers, but given the stagnation in fish production in the state, the internal demand has far outweighed the external demand (MSAM, 2012). This has led to increasing imports from coastal states like Andhra Pradesh and Tamil Nadu. Considering the remoteness of Meghalaya and inexis-

tence of efficient transportation corridors, it is evident that the government has to allot a good chunk of money to provide for the deficit fish demand. The stagnated growth in fish production of Meghalaya has been shown in Figure 2.

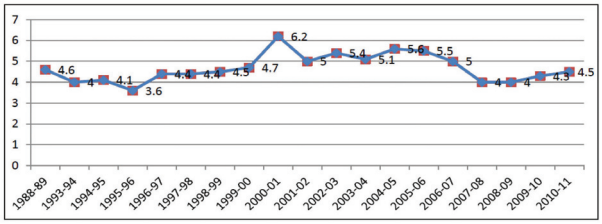

Fig. 2. Fish production in Meghalaya ('000 tons)
Source: Directorate of Economics and Statistics, Government of Meghalaya

When the fish production scenario is compared with the population statistics of Meghalaya, a visible picture of demand deficit comes into being. According to the Census 2011, the state had its highest population growth of about 2.5% per annuum for the period 2001-2011. Stagnation in production and fish being a staple food of the region, per capita availability of fish has evidently declined in the state. Additionally, this has led to a significant downturn of the contribution of fisheries to the gross state domestic product (GSDP) from agriculture and also, the total GSDP. Specifically, the revenue from fish production has fallen down to 0.21% of overall GSDP and 1.15% of total agricultural GSDP, whereas the national averages are approximately 1% and 5.20% respectively (Statistical Handbook, Government of Meghalaya, 2017).

Tasek lake is located in the East Garo hills district. Official data indicates the same underlying stagnated trend of fishery development in the district, or even a deteriorating trend, as seen from table 4. There has been a negligible growth in fish seedling distribution and the negative growth in fish farms has aggravated the demoralizing nature of fishery development. Besides this, the unavailability of data at the hands of the Fishery department further showcased its lackadaisical attitude.

The positive relationship between livelihood status of people and aquaculture is inevitable. There has been dearth of studies completed in this particular aspect and our specification of results depends upon government reports and interactions with villagers. A report published by State Institute of Rural Development (SIRD), Meghalaya cites that about 65% of the villagers that are involved in fish farming in East Garo Hills, have done it only for selling purposes. This indicates the inclination of fish farmers towards reaping economic benefits from aquaculture, rather than personal consumption. Interestingly, it has been noted that the highest number of

Table 1. Month-wise fluctuation in Numerical Abundance of Plankton (u/l) in Tasek Lake for the year 2018

Group	Months												Average
Phytoplankton	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	
Myxophyceae	59	2352	1398	1316	765	1165	215	6	35	29	12	28	614
Chlorophyceae	1554	2021	89	33	47	294	750	1040	903	684	611	841	739
Cyanophyceae	1680	39	—	—	—	—	—	—	—	172	310	1316	293
Bacillariophyceae	1950	556	2637	2723	112	78	209	43	698	512	413	752	890
Dinophyceae	—	—	—	—	65	589	870	369	518	862	490	32	890
Euglenineae	20	—	10	—	—	—	—	—	—	—	—	—	3
Chrysophyceae	—	6	—	—	6	—	—	—	78	—	—	—	7
Total	5263	4974	4134	4072	995	2126	2044	1458	2232	2249	1636	2969	
Zooplankton													
Rotifera	59	37	24	28	7	16	60	30	35	40	23	31	33
Cladocerona	37	50	20	40	20	17	82	58	45	16	27	30	37
Copepoda	18	20	10	21	5	32	70	11	58	8	10	30	25
Total	114	117	54	89	32	65	212	99	138	64	60	91	
Total Plankton	5377	5191	4188	4161	1027	2191	2256	1557	2370	2313	1696	3060	

Group	**Total**	**Percentage**
Phytoplankton	34,346	96.80%
Zooplankton	1,135	3.20%
Plankton	**35,287**	**100%**

people engaged in fish farming were from East Garo Hills. For instance, at least 105 villagers were engaged in it (for 0-5 years) in East Garo Hills whereas the number hovered around 50-60 in other districts. However, the catch came into play when it was witnessed that in the long term, these fish farmers had the lowest probability of continuing fish farming- only about 28 people continued (for 6-10 years) compared to 43 of East Khasi Hills. Nevertheless, regarding ease of access to financial resources and credit facilities, a positive trend has been witnessed. The primary hurdle was observed in implementational status of fishery development schemes, wherein, total ponds for fish farming was seen to be much less in East Garo Hills (15 hectares) compared to remaining districts of Meghalaya. A critical observation pertaining to the trade-off between fishery and other forms of livelihood was documented when majority of the farmers (more than 90%) responded negatively to the prospect of giving up their current business to start up a fish farm. Most considered it to be a part time activity and hence, used mainly traditional methods for fish production. Besides that, a lack of technical and financial incentives from the authorities to hand-hold farmers in switching to better fish varieties and develop associated infrastructure has led to the deteriorating state of fish production in the region.

Nevertheless, interventions in fish farming, has led to a more or less positive effect upon the population of East Garo Hills, as depicted in the figure below. The data involved pertains to the recorded responses of villagers in the state. A significant majority has responded positively towards increase in their standard of living owing to increase in their financial ability to take care of their families and an enhanced ability to employ more people in farm due to increased incomes. Food security has also been accorded with positiveness but in East Garo Hills, positive responses were a minority. This depicts an ironical picture wherein standard of living has increased due to high incomes whereas food security has remained momentum-less, which has been a noticeable trend in most developing nations.

As was observed during the field study, Tesak lake forms a pivot point in the context of fishery development in East Garo Hills. A talk with the villagers made it evident that they were aware of the benefits of fisheries and the potential of Tesak lake

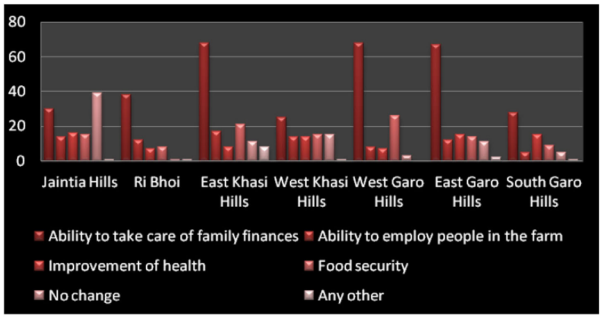

Fig. 3. Fish farming and related change in parameters of living standards in Meghalaya
Source: Department of Agriculture, Meghalaya

Table 2. Month-wise variation of physico-chemical parameters corresponding to plankton population u/l in 2018 of Tasek lake

Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean	SD (±)
pH	5.00	5.00	5.25	6.00	6.50	6.50	6.50	6.70	6.20	6.00	6.00	5.25	5.91	0.60
Water (°C)	14.50	14.90	20.00	23.00	26.00	26.50	30.50	29.50	26.00	25.50	23.00	15.00	23.41	5.67
Conductivity ()	18.50	19.00	16.00	17.50	15.50	23.50	24.00	22.50	23.00	20.00	20.25	18.00	19.71	2.78
Transparency	60.00	62.00	65.00	65.50	65.50	70.00	75.00	88.00	85.00	80.50	75.00	70.00	71.79	8.66
Hardness (mg/L)	65.00	67.00	78.00	80.00	69.00	63.00	50.00	56.00	70.20	67.00	70.00	69.00	67.00	7.88
Chloride (mg/L)	6.75	11.50	8.90	8.90	11.50	11.75	13.00	14.50	15.00	14.75	12.50	6.90	11.33	2.77
Magnesium (mg/L)	7.00	6.50	6.50	7.90	12.50	12.75	14.00	12.10	10.50	9.75	8.50	7.50	9.63	2.57
Alkalinity (mg/L)	13.00	12.50	10.00	9.00	9.50	9.00	10.00	10.50	12.50	13.00	16.50	15.00	11.71	2.33
Phosphate (mg/L)	0.06	0.04	0.03	0.03	0.03	0.05	0.05	0.01	T	0.00	T	0.01	0.03	0.02
Nitrate (mg/L)	T	T	T	0.03	0.04	0.04	0.04	0.01	0.03	0.01	T	T	0.03	0.01
Iron (mg/L)	T	T	0.13	0.11	0.10	0.12	0.12	0.11	T	T	T	0.11	0.11	0.01
Free CO2 (mg/L)	1.50	1.00	0.95	0.45	0.50	1.00	1.50	2.00	2.50	2.50	2.00	2.00	1.49	0.07
D.O. (mg/L)	12.10	11.15	11.02	7.79	6.86	7.09	7.80	6.60	6.20	7.53	9.64	12.35	8.85	2.19
BOD (mg/L)	3.10	3.00	3.00	2.60	2.50	2.30	2.00	2.22	2.50	2.90	2.95	3.00	2.67	0.35
COD (mg/L)	16.50	20.50	22.00	23.00	22.50	25.00	21.00	29.00	30.00	30.25	22.00	20.00	23.48	4.11
Y= Total Plankton	5377	5191	4188	4161	1027	2191	2256	1557	2370	2313	1696	3060		

Table 3. Correlation Coefficient for Tesak Lake for the year 2018

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15
x1	1.000	0.9851	0.5323	-0.6357	-0.253	-0.6852	-0.9086	-0.4339	-0.559	-0.6097	-0.359	0.666	-0.9193	-0.871	0.6054
x2		1.000	0.5667	0.6856	-0.2658	0.7602	0.8747	-0.4639	-0.0642	-0.3407	-0.0748	0.1299	-0.9146	-0.8596	0.6614
x3			1.000	0.6563	-0.6357	0.6027	0.6079	-0.197	-0.1645	-0.1692	0.2477	0.4988	-0.4902	-0.6415	0.4398
x4				1.000	-0.2588	-0.7956	0.5127	-0.126	-0.5856	-0.1377	-0.908	0.745	-0.6422	-0.4898	0.8399
x5					1.000	-0.3925	-0.5175	0.3310	-0.1606	0.1655	0.0111	-0.2117	0.1362	0.4835	0.0099
x6						1.000	0.6085	-0.0632	-0.2925	0.127	-0.826	0.4859	-0.7845	-0.5349	0.8117
x7							1.000	-0.4543	0.1142	-0.2434	-0.2324	0.0599	-0.7968	-0.9085	0.4218
x8								1.000	-0.4299	0.455	-0.1459	0.6494	0.4934	0.6165	-0.1442
x9									1.000	-0.3048	-0.4063	-0.5725	0.0886	-0.1789	-0.5998
x10										1.000	0.2499	0.2311	0.4339	0.6653	0.1741
x11											1.000	0.79	-0.7915	0.1141	-0.1221
x12												1.000	0.0841	-0.725	0.4905
x13													1.000	0.7819	-0.7726
x14														1.000	-0.3932
x15															1.000

in terms of the lake species diversity and a favorable locational aspect. It had been the implementational aspect that was lacking. It was also observed that building a tourism spot and maintaining a fishery, was highly contradicting. Fish farming needs an undisturbed environment wherein they can breed well. Policy consonance was also found to be inexistent in case of Tesak lake.

Discussion

In the present study, it has been found out that different plankters were found to thrive well in different temperatures. Myxophyceae among phytoplankton was abundant during the low temperature period while Chlorophyceae and Bacillariophyceae were more abundant in high temperature. Among zooplankton, rotifers were predominantly confined to winter months also stated that the rotifers showed an inverse correlation with temperature in the Hooghly-Matlah estuarine system.

As regards physico-chemical parameters are concerned, pH is an important factor in chemical and biological system of natural water as the toxicity of many compounds are greatly affected with change in pH. In Tasek lake, the range of pH was 5.0 to 6.70. This implied that the Tasek lake water was alkaline in all the months of the year may be due to the use of different kinds of manure applied by the fishery department; corroborating the study of Hazarika and Dutta (1994, 1997).

Water temperature of Tasek lake varied between 19.20 °C to 30.5 °C in the year. The range of water temperature recorded in this investigation broadly corresponded with the observation in some other water bodies of the state of Assam (Dey and Lahon 1979; Dey 1981; Dey *et al.*, 1987). Temperature was considered to be an important physical factor which influenced chemical changes in water (Wetzel, 1983; Vass, 1989). This generalization particularly is true in the study of JongalBalahu, as water temperature showed significant relationship with other parameters.

Conductivity represents the amount of total dissolved substances present in water and is a measure of resistance offered by them to electric flow. The present study showed considerable variation in their specific conductivities and hence, in overall ionic spectrum of their water quality. The conductivity of Tasek lake ranged from 17.50 µhos to 24.00

Table 4. Fish seedling distribution and Fish farming data, Meghalaya

Particulars	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
Fish seedling distribution ('000 no.)	1456	358	1153	1153	179	1041
Fish farms	—	—	3	3	2	2

Source: Directorate of Fisheries, Meghalaya; Statistical Handbook of Meghalaya, 2017

µhos confirming its water to be quite soft, which corroborates the findings of Khan (1987).

The transparency in Tasek lake which is a managed pond ranged between 60.00 cm. to 88.00 cm. It can well be observed that the values of transparency were low in the month of May, June and July, which corroborates with the observations by Jhingran *et al.* (1964). This may be attributed to the allochthonous turbidity caused due to rain water.

Hardness in the present investigated site exhibited a good variation. The hardness ranged between 50.0 mg/L to 80.0 mg/L. Thus, the present investigated site can be categorized as a very hard water body.

As regards concentration of chloride is concerned it can be considered as an index of organic pollution caused due to inflow of domestic waste water (Thresh *et al.,* 1944). The chloride content ranged between 6.75 mg/L to 15.00 mg/L. But it is to be noted that the present investigation registered a slight increase in the chloride level during monsoon which should be attributed to its import from the catchment area with rain water.

The present investigated site with high values of alkalinity may be due to carbonate and bicarbonate both; corroborating the findings of Dey (1981), which may be due to the decomposition of the hydrophytes present in the lake.

As regards the free CO_2 is concerned it ranged between 0.45 mg/L to 2.50 mg/L, which is moderate corroborating the observations of Kar (1984) and Goswami (1985). Moreover, the high value of free CO_2 in certain months may be attributed to the decomposition of hydrophytes as also reported by Allegier *et al.* (1932).

Regarding the interrelationships of different physico-chemical factors, the correlation coefficient for Tasek Lake for the year 2018 was computed and it shows that pH showed direct relation with hardness (r = .87) and inverse relationship with conductivity and alkalinity.

Temperature showed significant relationship with other parameters of which correlation-coefficients for the year 2018 may be given as; the water temperature showed direct relationship with conductivity, magnesium and transparency with "r" values of (r = .56, r = .87, r = .68, r = 93) respectively and inverse relationship with hardness (r = –.) and alkalinity (–.26), corroborating the finding of Bhuyan (1970).

Conductivity of the fish pond showed direct relation with chloride (r = .60) and inverse relation with hardness (r = .91) and alkalinity (r = -.19). On the other hand, transparency showed inverse relation with alkalinity (r = –.12). Inverse relation was also observed with chloride (r = -.79) and phosphate (r = –.58). Consequently, in Tasek lake, free CO_2 showed indirect relationship with dissolved oxygen (r = –.79).

As regards the other statistical analysis are concerned, the relationship between plankton and various physico-chemical parameters have been observed through statistical methodology as given before and the findings are given below for Tasek lake in the year 2018.

Site: Tasek Lake, 2018

$Y = + 38842.8676 — .9197x1 + .3784x2 + .3511x3 + .4759x4— .3215x5 + .9058x6 — .2380x7 + .2399x8 — .0784x9 — .2350x10 + .2474x11 + .2350x12 + .1862x13 + .2881x14 + .2564x15$

$R^2 = 0.7944$, significant.

Thus, it can be found out that the different ecological parameters have had their immense influence on the plankton abundance. When different environmental factors jointly influence, then there must be variation in the abundance of plankton. In this study it is found that in multiple regression two variables tend to increase or decrease together does not necessarily imply that one variable has direct or indirect effect on the other; both may be influenced by other variables in such a way, so as to give a strong mathematical relationship.

All the parameters considered here in the present study give coefficient of determination to be 79 %in the Tasek lake. Thus, F-statistics for analysis has been found to be highly significant. The remaining percentage of variation (which is quite negligible) is not explained by regression model perhaps due to

non-inclusion of certain important factors.

Regarding Tasek lake, the present investigation showed the presence of 43 different fish species of 8 orders and 12 families. The National Bureau of Fish Genetic Resources (NBFGR) had initially prepared an exclusive list of species from cold and warm fresh water as potential fishes for listing under threatened fishes of India. A list of threatened fish of India was prepared by Mahanta *et al.*, 1994, was consulted and found that fish species were categorized under following categories such as endangered, rare indeterminate vulnerable an extinct. But the present study in Tasek Lake only vulnerable and indeterminate forms could be identified.

From the list of icthyospecies from Tasek Lake the fish species which are categorised as indeterminate and vulnerable may be given as follows:

A. Indeterminate:
1. *Gadusiachapra* (Hamilton)
2. *Mastacembelusarmatusarmatus* (Lacepede)
3. *Notopteruschitala* (Hamilton)
4. *Tor tor* (Hamilton)

B. Vulnerable:
1. *Labeo dero* (Hamilton)
2. *Psilorhynchusbalitora* (Hamilton)
3. *Tor putitora* (Hamilton)

On the other hand, if we consider zoo-geographical classification then it will be found that Jayaram (1974), divided the fresh water fishes into primary and secondary groups, whereas Mirza (1975) classified the fresh water fishes into three categories namely primary, secondary and peripheral forms.

The fish fauna of Tasek Lake (Meghalaya) is composed of mainly primary and peripheral fresh water forms. The secondary fresh water form is found to be absent in the whole Meghalaya region, as reported by Sen (1982). 91.35% of Meghalayan fishes are primary freshwater forms and only 8.65% is peripheral forms. Of the primary forms 48.42% belong to the family Cyprinidae and rest 51.58% include Notopteridae, Psylorhynchidae, Cobitidae, Bagridae, Amblycipitidae, Nandidae, Anabantidae, etc. It is to be noted that some species of family Cyprinidae such as *Garanasuta, Garagotyalagotyala*, are of great geographical importance to Tasek Lake as they are found to be torrential forms.

In the context of economic significance of the Tasek lake, tremendous potential in terms of fishery development was witnessed. Needless to mention, the lake also bears great aesthetic value and can be formed into a major tourist attraction. However, the current status of implementation of both these aspects haven't materialised in a way that can benefit the livelihood of its fringe villagers. Nevertheless, it is pertinent that the economic valuation of the lake should be put to use and a sustainable pathway is designed so that its abundant resources are exploited efficiently. Firstly, productivity enhancement could be done through reclamation of marshy and swampy areas nearby so as to expand the area of fish farming and processing activities. Fingerlings should be stocked in proper reservoirs or smaller water bodies. Secondly, In case of infrastructure, a public-private participation model could be implemented which has already witnessed success in several parts of the state? A fish-disease management laboratory could also be established in the vicinity to contain outbreak of any diseases. Aquaculture training centres and entrepreneurship development courses should be launched for local youth. Thirdly, fishery or multi-purpose cooperatives could be exclusively set up to rope in local communities in community farming and managing the lake while reaping the dividends of such activities together. Finally, the concept of aqua tourism and sport fisheries as well as creation of ornamental or aquarium fisheries, trout farming and freshwater prawn culture should be given serious thought. This would have an exponential effect on the livelihood status of the local dwellers while bridging the food security and demand gap of the state.

Therefore, from the ecological context of Tasek lake, maintaining its fish diversity would require management and restoration of its aquatic terrestrial ecotones. This will in turn have an incredible effect on the environmental value and livelihood status of local people and the state of Meghalaya.

Acknowledgement

We would like to thank the Directorate of Economics and Statistics, Department of Agriculture, Department of Fisheries and Department of Tourism, Government of Meghalaya for their incredible assistance and support throughout the study. Thanks to the villagers near Tasek Lake, Assam for helping us in the limnological investigation and providing relevant valuable inputs regarding their economic issues. Thanks to Cotton University and peers of Gauhati University for their never-ending motivation during the course of the study.

References

Allegier, K. J., Peterson, W. H., Juday, C. and Birge, E. A. 1932. The anaerobic fermentation of lake deposits. *Int. Rev. d. ges. Hydrobiol. u. Hydrogr*. 26 : 444 – 461.

APHA, 1989. *Standard Methods for the Examination of Water and Waste Water*, 17th Edition. Washington D.C.

Bhuyan, B.R. 1970. Physico-chemical qualities of the water of some ancient tanks in Sibsagar. *Assam. Environ. Health*. 12: 129 – 134.

Christophe, B. 2009. *Small-scale fisheries: assessing their contribution to rural livelihoods in developing countries,* Food and Agriculture Organization Discussion Paper.

Das. S.M. and Srivastava. V.K. 1956. Quantitative studies on freshwater plankton II, Correlation between plankton and hydrological factors. *Proc. Nat. Acad. Sci., India*. 26 (4): 243 – 2543.

Das, P.K. 1980.*Studies on limnology of Tasek Lake and adjacent water bodies in Garo Hills, Meghalaya*, Doctoral thesis, NEHU, Shillong. India.

Dey, S.C. and Lahon, B., 1979. Observations on the interrelationship of fish population in an ox-bow lake of Assam, India. *Proc. All-India Sem. Ichthyology*. 2 : 29.

Dey, S.C. 1981. *Studies on the hydrobiological conditions of some commercially important lakes (Beels) of Kamrup district of Assam and their bearing of fish production.* Final Technical Project Report, North-Eastern Council (Govt. of India), 177.

Dey, S.C. and Kar, D. 1987. Physico-chemical complexes of water and soil in Sone, and ichthyological potential tectonic lake of Assam. *J. Assam Sci. Soc*. 30 (1): 1–11.

Directorate of Economics and Statistics, 2017. *Statistical Hand Book,* Meghalaya, Government of Meghalaya, Shillong.

Dutta, A., Kalita J., M. Nuvaid, Sheikh M.S., and Sarmah, D. 1993. Diurnal variations of certain physico-chemical parameters of two standing water bodies in the vicinity. *Environment & Ecology*. 11 (14) : 820 – 824.

Allision, E., and Ellis, F., 2001. The livelihoods approach and management of small-scale fisheries. *Marine Policy.* 25 : 377-388.

Fish Farmers Development Agencye, 2012. *Meghalaya State Aquaculture Mission Document, 2012-2017,* Government of Meghalaya.

George, M. G. 1961 a. Diurnal variation in two shallow ponds in Delhi, India. *Hydrobiologia.* 18 (3): 265 – 273.

George, M. G. 1961 b. Observation of ratifiers from shallow ponds in Delhi. *Cur. Sci.* 30 : 268-269.

Goswami, M. M. 1985. *Limnological investigation of a tectonic lake of Assam, India and their bearing on fish production*. Unpublished Ph.D. Thesis, Gauhati Univ. Assam: 395.

Hazarika Arup Kr. and Dutta A. 1994. Limnological Studies of two fresh water ponds of Guwahati, Assam. *Environ and Ecol.* 12 (1): 26 – 29.

Hazarika, Arup Kr and Dutta, A. 1997. A study of Tasek Lake of Garo Hills (Meghalaya). *Environ. and Ecol.* 15 (2): 397-402.

Hazarika, Arup Kr and Dutta, A. 1998. Interrelationship of Certain Physico-Chemical Parameters and Plankton Community of Tasek Lake (Meghalaya). *Environ and Ecol* 16 (3) : 561-567.

Jayaram, K.C. 1974. *Ecology and Distribution of Fresh Water Fishes, Amphibians and Reptiles in*. Ecology and Biography in India, B.V. Publishers, The Hague. 517-584.

Jhingran, A.G., David, A. and Roy, P. 1964. *Death by cold of fish in the river Gandak, India. J. Bombay Nat. Hist. Sci.* 61 (1) : 195 – 200.

Kar, D. 1984. *Limnology and fisheries of Lake Sone in Cachar district of Assam, India.* Unpublished Ph.D. thesis Gauhati Univ., 201.

Khan, H.A. 1987. Observations of Zooplankton composition, abundance and periodicity in two flood-plain lakes of the Kashmir Himalayan Valley. *Acta. Hydrochim. Hydrobiol*. 15 (2) : 167–174.

Lahon, B. 1983. *Limnology and Fisheries of some commercial beels of Assam, India.* Unpublished Ph. D. Thesis. Gauhati. Univ. Assam, 351.

Lyngwa, T. 2015. *Impact Assessment of The Thousand Ponds Scheme*, Report of the State Institute of Rural Development, Nongsder.

Mahanta, P.C., Kapoor D., Dayal R., and Ponniah A.G., 1994. *Prioritization of Indian Fish Species for Conservation, Threatened Fishes of India* (eds P.V. Dehadrai, P. Das, S.R. Verma) Nature Conservators, Muzaffar Nagar.

Mirza, M.R. 1975. *Fresh Water Fishes and Zoogeography of Pakistan*; Bidin. Dierk: 45(2): 143-180.

Philipose, M.T. 1960. Freshwater phytoplankton of inland fisheries. *Proc. symp. Algol.* ICAR, New Delhi: 272–291.

Reid, G.K. 1961. *Ecology of Inland Waters and Estuaries*. Rienhold Publication corporation. New York.

Sen, N. 1982. *Studies on the systematics, distribution and ecology of ichthyo fauna of Meghalaya and their bearing on the fish and fisheries of the State*. Unpublished Ph. D. Thesis, Gauhati Univ.

Thresh, J.C. Suckling, E.V. and Beale, J.F. 1944. *The Examination of Water Supplies*, Ed. by E.W. Taylor.

Trivedy, R.K. and Goel, P.K. 1986. *Chemical and Biological Methods for Water Pollution Studies*. 2nd. Edi. Environmental Publication. Karad, India.

Vass, K.K. 1989. Productivity status of beels in India, Cent. Intl. Cap. Fish. Res. Institute, Barrackpore. *Bull.* 63 : 57 – 64.

Wetzel, R.G. 1983, *Limnology*, 2nd edn., Sanders College Publishing.