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APPLICATION OF GIS FOR THE STUDY OF THE FISH DIVERSITY AND HABITAT PARAMETERS IN THE WETLANDS OF BARAK VELLY WITH SPECIAL EMPHASIS ON SONE BEEL; THE BIGGEST WETLAND OF ASSAM

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ABSTRACT

Water is 'life' and life is 'water;' 'Life' is said to have originated in water. Water makes up *c* 80 % of the living body. Electrolytes dissolved in water readily ionize because water molecules are polar solvents of high dielectric constant. Ionisation and ionic reactions are of great importance to life. Water is contained in water bodies, which are of two basic waters, *viz.*, (a) those which are flowing called lotic systems; and, those which are stagnant and water does not flow are called lentic systems.The present communication deals with a panorama of wetlands in Assam (North-East India), with special emphasis on Sone Beel, the biggest (area, 3458.12 ha at FSL) wetland in Assam. Different aspects of Sone Beel, notably the physico-chemical, biological, and geographical characteristics , have been discussed in the paper. Attempts have been made to portray change detection of water-spread area, use of water area; as well as, suitability of the habitat, etc., on a GIS platform.

INTRODUCTION

'Life' is said to have originated in water. Water makes up *c* 80 % of the living body. Electrolytes dissolved in water readily ionize because water molecules are polar solvents of high dielectric constant. Ionisation and ionic reactions are of great importance to life. The FW habitats could be broadly classified into two categories, viz., (a) The Lentic system or the standing water series, (b) The Lotic system or the running water series

The former includes the lakes, wetlands, tanks, ponds, marshes, fens, bogs in a sequential manner from big to small size. The system also includes the artificially-made reservoirs. The latter system contains the rivers, streams, tributaries and the brooks in successive series of big to small size.

THE LENTIC SYSTEM (The standing water series): Although the name is 'standing water', actually, the water in such bodies is in motion in different ways. Hence, 'standing water' does not necessarily mean 'static'. It simply means that water does not flow.

WETLANDS: 'Wetlands' are basically 'wet-lands' where the soil is saturated with water for sometime during the year. According to IUCN (1970), wetlands are areas of marsh, fen, etc., temporary of permanent; natural or artificial mass of water, the depth of which generally does not exceed 6 m. Wetlands are areas which contain substantial amount of standing water and little flow. In Assam, and in adjoining Tripura and Bangladesh, 3 kinds of wetlands are generally found. They are locally(local names may vary) called as follows:

a) 'Beel': Perennial wetlands which contain water throughout the year.
b) 'Haor': Seasonal wetlands which contain water for some period of the year only, particularly, during the rainy season. As such, they are also called 'floodplain wetlands'.
c) 'Anua': These are peculiar river-formed perennial oxbow-type wetlands which are generally formed due to change in river course and which may or may not retain connection with the original river.

Wetlands in North-East India: Situated between 89-97° E Longitude and 20-30° N Latitude, the region encompasses a vast area of 2,55,083 sq km out of total Indian area of 3.3 million sq km. Besides lotic territories, the lentic water bodies having 0.72 x 10^6 ha lake coverage in India, constitute great potential of fishery resources. The NE region is blessed with a number of lentic systems, locally called `Beel, Haor, Anua, Hola, Doloni, Jalah, etc., which alone constitute *c* 81 % of the total lentic area (0.12 x $1o^6$ ha) in Assam. These lentic systems are generally shallow and open, ranging in size from 35 to 3458.12 ha and with depth ranging from 0.25 to 3.0 m (in some, however, the maximum depth may exceed 6.0 m) at LSL. Further, in Assam, there are *c* 1392 number of wetlands having a total of *c* 22,896 number of fisheries of different categories; out of which, the number of registered wetlands is only 394 (30.38 %) covering an area of *c* 70,000 ha; of which, *c* 19,000 ha is in good condition; *c* 15,000 ha is in semi-derelict condition and *c* 35,000 ha is in derelict condition (Govt. of Assam, 2006).

LIMNOLOGY OF THE MAJOR LENTIC WATER BODIES

In Assam, many wetlands are unregistered and under the control of both government and private sectors. In this context, the district of Cachar is said to include the highest number of unregistered wetlands in Assam. An account of some of the prominent lentic bodies of Assam is given below:

Lentic bodies: Some of the significant lentic bodies in this region are given below:

i. Beel (Perennial wetland): Sone Beel, Sat Beel, etc.
ii. Haor (Seasonal floodplain wetland): Chatla Haor, Puneer Haor, etc.
iii. Anua (River-formed oxbow wetland): Baskandi Anua, Satkarakandi Anua, etc).

An account of each of the above-mentioned kinds of wetlands is briefly given below:

(a) **Sone Beel (Kar, 1990, 2007, 2013):** It is situated between 92 º 24' 50" – 92º 28' 25 " E and 24º 36' 40" – 24º 44' 30" N within Karimganj district of Assam and falls in a valley geologically called syncline.

The physiography of the district consists of small hillocks intervened by wide low valleys. The hillocks have NE-SW and NE-SSW trend near the Barail range and N-S trend towards south away from the Barail range. Notably, Sone Beel, the biggest 'Beel' (wetland) in Assam is situated in between two hill ranges, viz., the Badarpur-Saraspur range and the Chowkirmukh-Dohalia range.

The principal feeder of the wetland is the major inflow, the river Singla, which drains a total catchment area of *c* 46,105 ha. The wetland basin tended to become deeper from south to north. The contours in the west were found to be almost parallel and closer than their counterparts in the east.

Although 12 minor inlets were found to exist in different parts of the wetland, the wetland is

mainly fed with the major inlet, the river Singla. It originates as 'Thing Tlawng Lui' at a height of *c* 365.21 m MSL in Mizo Hills, from where, after traversing a meander course of *c* 62.75 km, it enters Sone Beel.

The major outflow (there being no minor outflow) of the wetland, the river Kachua originates from the northern- most end of the wetland. It drains out the wetland water into the mighty river Kushiara after covering a length of *c* 19.30 km. Although the river Kachua was blocked by a blind dam constructed by the Government of Assam in 1950-51, the dam was replaced by a lock gate in 1964 after experiencing navigational and fishery problems.

Dimensions of Sone Beel: FSL: 1.Maximum length (L)=12.5 km;; 2.Maximum Breadth (B)=3.9 km. Area=3458.12 ha
DSL: .Max L = 4.07 km; 2.Max B= 2.22 km; 3.Area=409.37 ha; L of Shoreline= 35.4 km; Shore Development= 1.69; Volume Development= 0.15; Mean Depth= 0.29
Gross Volume= 101.54 x 10^6 m^3

Hydrodynamics of Sone Beel

a) Major Inlet 'Singla' , or 'Thing Tlawng Lui', from Mizoram, 72 km., draining catchment 46105 ha; inflow 33.91 m3/sec
b) Major outlet 'Kachua' from Sone Beel. 19 km, outflow 87.03 m3/sec
c) 'Kachua' was blocked by Assam Govt. with 'blind dam' in 1951; then, replaced by a 'lockgate' in 1964, which is functional in a nominal way now.

Silt deposition by Inlet (R.Singa)= 27 – 350 mg/l
Silt expulsion by outlet (R. Kachua)= 9 – 88.1 mg/l

Physico-chemical characteristics of water of Sone Beel in Assam (Kar, 1990)

In Sone Beel wetland, the water was found to exhibit interesting trend in its physico-chemical features.

Water colour and turbidity: The turbidity of the Beel water generally fluctuates from 24.21 to 185.54 TU at the surface and 20.56 to 183.36 TU at the bottom level.

Silt load: The silt load at the **inlet**, measured at the Beel mouth was found to vary from **27.0 to 350.0 mg/lit**. Concomitantly, the values for the **outlet water** was found to fluctuate usually from **9.0 to 88.1 mg/lit**. The overall result indicated that more amount of silt is retained and deposited in the Beel and lesser amount is expelled through the outlet thereby resulting in overall siltation of the Beel.

Temperature: The surface water temperature generally lies between 18.7 to 32.3 C while the bottom water temperature generally range from 19.2 to 32.1 C.

pH: The pH values, when measured with electronic pH meter at the laboratory after collecting samples from the field, generally vary from 6.67 to 7.90 at the surface level and 6.61 to 7.79 at the bottom level.

Dissolved Oxygen (DO): DO values generally fluctuate from 2.61 to 5.96 mg/lit in the surface water and 2.43 to 5.84 mg/lit in the bottom water.

Free carbon di-oxide (FCO_2): FCO_2 was found to vary from 1.75 to 11.8 mg/lit at the surface water level while it fluctuated from 0.90 to 14.55 mg/lit at the bottom water level.

Total Alkalinity (TA): TA generally lies between 28.5 to 74.31 mg/lit at the surface water 25.0 to 76.01 mg/lit at the bottom water.

Specific Conductivity (SC): It usually ranges from 51.98 x 10^{-6} to 89.09 x 10^{-6} mhos/cm at

the surface water level and 52.5 x 10^{-6} to 156.66 x 10^{-6} mhos/cm at the bottom water level.

Physico-chemical characteristics of soil of Sone Beel in Assam (Kar, 1990): The values of various physico-chemical characteristics of soil of Sone Beel in Assam are given below:

Temperature (C) : 19.9 – 32.3; pH : 5.09 – 5.99; Conductivity (µmhos/cm at 25 C) : 47.42 – 322.08; Organic Carbon (%) : 0.25 – 1.74; Available Phosphorus (mg/100 g) : 0.15 – 1.93; Available Potassium (mg/100 g) : 1.6 – 24.8

An account of Limnoplankton of Sone Beel (Kar, 1990, 2007, 2010, 2013)

47 different forms of phytoplankton belonging to five groups, as indicated above, have been recorded, till date, in Sone Beel. Of these, the Chrysophyta included the maximum number and Pyrrophyta, the least. The phytoplankton density in the Beel varied from 48-5308 (average 1027) units/lit.

19 different forms of zooplankton, belonging to five groups, as indicated above, have been recorded, till date, in Sone Beel. The zooplankton density varied from 6-380 (average 49) units/lit.

An account of Aquatic Macrophytes of Sone Beel (depicting species composition, phyto-sociology, standing crop and seasonal succession) (Dey and Kar, 1989 a; Kar, 2007, 2010, 2013). AM was found to exhibit a heterogeneous assemblage of 23 species in Sone Beel. AM biomass was found to vary from 0.58 – 21.90 kg/m^2 (average 2.48 ± 0.82) having the maximum in December and the minimum in May. High Species diversity among the AM species were evident in this wetland. And, the level was found to be high (biassed estimate of *H'* = 2.015; expected value, *E (H')* = 2.014; variance of *H'* = 1.431 *E*-3) in Sone Beel.

(b) Chatla Haor (Kar and Barbhuiya, 2000 b; Kar, 2007, 2010, 2013)

It is situated between 93º15' N to 24º 10' E in the Cachar district of Assam. Having a water spread area of *c* 1600 ha at the FSL, Chatla is considered as one of the biggest 'Haor' in Assam.

The maximum length (L), breadth(B), depth(D) and water spread area(A) of the wetland at FSL have been measured to be 10 km, 2.5 km, 5.5 m and 1600 ha respectively.

Physico-chemcical characteristics of water of Chatla Haor in Assam (Kar and Barbhuiya, 2000 b)

The following are the results of analysis of the physico-chemical characteristics of water of Chatla Haor: Temperature (C) 33 ; Turbidity (NTU): 83.27; pH : 6.09; FCO_2 : 7.59 mg/lit; TA : 83.39 mg/lit; Conductivity: 142.91 micromhos/cm

An account of Zooplankton of Chatla Haor Wetland (Kar and Barbhuiya, 2004)
Studies conducted in *c* 1600 ha Chatla Haor in Cachar district revealed the occurrence of 18 species of zooplankton consisting of 2 species each of Protozoa and Copepoda, 6 species of Rotifera and 8 species of Cladocera. (Kar and Barbhuiya, 2004; Kar, 2013)..

An account of the AM of Chatla Haor seasonal floodplain wetland (Kar and Barbhuiya, 2001)
23 species of AM could be recorded, till date, in the 1600 ha (at FSL) Chatla Haor situated in the Cachar district of Assam. These could be classified as follows:

5 free floating, 4 rooted floating, 2 submerged

and 12 emergent. Of these, 6 AM species could be found throughout the year. These are: *Azolla pinnata, Eichhornia crassipes, Salvinia cucullata, Trapa bispinosa, Jussiaea repens* and *Cynodon dactylon.*

(c) **Baskandi Anua:** This oxbow wetland is situated between 24º 10' N (latitude) and 93º 15' E (longitude) in the Lakhipur Sub-division of Cachar district in Assam.

The L, B and A of Baskandi Anua have been found to be respectively 2.230 km, 205 m and 39.2 ha at FSL and 2.090 km, 190 m and 36.7 ha at DSL.

An account of the AM of Baskandi Auua (Dhar et al., 2004)

16 species of AM have been recorded in the 39.2 ha (at FSL) Baskandi Anua which belong to 6 free-floating (*Azolla pinnata, Echhornia crassipes, Salvinia cucullata, Lemna pausicostata, Pistia stratiotes, Wolfia* sp); 2 rooted submerged (*Hydrilla verticillata, Vallisneria spiralis)*; 6 rooted with floating leaves (*Nymphaea nouchali, Nymphoides indicum, N.cristatum, Trapa bispinosa, Euryale ferox, Nelumbo nucifera)*; and 2 rooted emergent (*Jussiaea repens, Muradania nudiflora*).

ICHTHYODIVERSITY

The hills and the undulating valleys of the NE region of India give rise to large number of torrential hill streams and associated wetlands, which, finally become part of the Ganga-Brahmaputra-Barak-Chindwin-Kolodyne-Gomati-Meghna system (Kar, 2000 a, 2007, 2010, 2013). A novel approach related to the study of Fish assemblage structure and species inventory and habitat requirement of individual ichthyospecies in the assemblage in about 52 rivers and about 273 wetlands in North-East India have been undertaken and results reported by Kar (2001,2002, 2003, 2004, 2005, 2007. 20010, 2012, 2013, 2014), Kar and Sen (2007), Kar *et.al*, (2003, 2005, 2006, 2008, 2009, 2010, 2011, 2012, 2013, 2014) .

(a) Fish Diversity in Sone Beel of Assam: 70 species of fishes belonging to 49 genera under 24 families and 11 orders have been recorded in Sone Beel, the biggest wetland in Assam. The ichthyospecies are listed below systematically:

1.Pisodonophis boro
2.Gudusia chapra
3.Hilsa (Tenualosa)ilisha
4.Chitala chitala
5.Notopterus notopterus
6.Amblypharyngodon mola
7.Aspidoparia morar
8.Barilius bendelisis
9.Catla catla
10.Cirrhinus mrigala
11.C. reba
12.Cyprinus carpio
13.Danio devario
14.Esomus danricus
15.Labeo bata
16.L.calbasu
17.L.gonius
18.L.nandina
19.L.rohita
32.Mystus corsula
33.M. tengara
34.M.vittatus
35.Aorichthys seenghala
36.Rita rita
37.Ompok bimaculatus
38. Wallago attu
39. Ailia coila
40 .Clupisoma atherinoides
41. C. garua
42. Eutropiichthys vacha
43. Silonia silondia
44. Pangasius pangasius
45. Gagata nangra
46. Glyptothorax telchitta
47Clarias batrachus
48.Heteropneustes fossilis
49.Chaca chaca
50.Xenentodon cancila
63.Glossogobius giuris
64.Anabas testudineus
66.Colisa fasciatus
67.Macrognathus aral
68.M .pancalus
69.Mastacembelus armatus
70.Tetraodon cutcutia

20.Puntius chola
21.P.conchonius
22.P.sarana sarana
23.P.ticto
24.Rasbora daniconius
25.R.elanga
26.Salmostoma bacaila
27.Botia dario
28.Lepidocephalus guntea
29.Acanthocobitis botia
30.Somileptes gongota
31.Mystus cavasius
51.Aplocheilus panchax
52.Channa gachua
53.C.marulius
54.C.punctatus
55.C.striata
56.Amphipnous cuchia
57.Parambassis baculis
58.Chanda nama
59. Badis badis
60.Nandus nandus
61.Rhinomugil corsula
62.Sicamugil cascasia

Of the 70 ichthyospecies of Sone Beel, 59 species under 39 genera belong to the Primary FW group while 11 species under 10 genera belong to the category of Peripheral FW group (Nichols, 1928; Darlington, 1957). On the other hand, on the basis of Indian and Extra-Indian Territorial Distribution (Motwani et al., 1962; Kar, 1990), 28 ichthyospecies of Sone could significantly be incorporated under two groups, viz., (a)Widely distributed species and (b)Species of Northern India. Further, among the other species, one species, viz., *Glyptothorax telchitta* was found to be a true hill stream form; while, five speices, viz., *Botia dario*, *Lepidocephalus guntea*, *Acanthocobitis botia*, *Somileptes gongota* and *Gagata nangra* were recorded as Semi-torrential forms (Dey, 1973). Thirtynine fish species were found to belong to the Plainwater group (Dey and Kar, 1990, 2013).

(b) Fish Diversity in Chatla Haor of Assam: 57 species of fishes, belonging to 28 genera, 17 families and 9 orders, have been recorded in Chatla Haor. They are listed below (Kar and Barbhuiya, 2000 b; Kar, 2013):

(c) Fish diversity in Baskandi Anua: 13 species of fishes belonging to 10 genera, 6 families and 4 orders have been recorded in Baskandi Anua (Kar, et.al., 2000 b; Kar, 2013; Dhar, 2004):

Fish yield from Sone Beel: Of the 70 ichthyospecies, 84.2 % belong to the Primary FW group while the rest are of peripheral class. The annual fish yield from the Beel was determined as 358.21 mt during 1979-80 and 312.16 mt during 1980-81 having an annual average yield of 355.18 mt. Per hectare fish yield was determined as 103.5 and 90.26 kg respectively during the investigating years (Kar, 1990).

(d) Fish yield from Chatla Haor: Of the 57 species, as revealed from our studies (Kar and Barbhuiya, 2000 b), Cypriniformes was found to constitute 32.3 % of the total fish population followed by Channiformes (22.8 %), Siluriformes (14.02 %), Clupeiformes (10.52 %), and Interestingly, among the clupeids, occurrence of *Hilsa (Tenualosa) ilisha* (0.000041%) is a remarkable feature in the distribution of the species in freshwater. Further, occurrence of advanced fry stages of hilsa (45.5 to 128.0 mm) is an exceptional feature in the zoogeography and biology of the fish.

Fish yield from the Anuas: The 'Anuas'are potential oxbow wetlands having, in general, rich population of *Gudusia chapra* and *Salmostoma bacaila* both of which together constitute *c* 45% of the total fish yield from

these oxbow wetlands.

INDIAN SHADS (HILSA) IN THE WETLANDS: The total landing of hilsa from Sone Beel was 163.5 kg during 1979-80 and 220.7 kg during 1980-81, the trend, thereby, showed per hectare yield of 0.055 kg during the investigating period (Kar, 2013)

OCCURRENCE OF ADVANCED FRY OF *Hilsa (Tenualosa) ilisha* IN THE WETLANDS: The anadromous fish hilsa, portrays a single run in the wetlands of Barak valley region of Assam (Kar and Dey,1982 a,b; Kar, 1990, 2007). **Occurrence of advanced fry of hilsa in the Beels and Haors of Assam had not been reported by any of the earlier workers** (Kar, 2013)

INDIAN MAJOR CARPS IN THE BEELS: The total landing of IMC from Sone Beel was 3,184.4 kg (0.86 % of the total fish yield) during 1979-80 and 1958.65 kg (0.61 % of the total fish yield) during 1980-81; the trend, thereby depicted average per hectare yield of 0.74 kg during invesgating period (Kar, 2013).

FISH CATCHING DEVICES IN THE WETLANDS OF NORTH-EAST INDIA (Kar, 2013): The various types of fishing gears used in Sone Beel are given below:

- **Hook and Line gears:** Lar barshi, Kupa barshi, Tanga barshi ;
- **Traps:** Dori, Gui, Paran, , Khati bundh
- **Trawls:** Chhat jal, Pelain
- **Scooping gears:** Dheki jal, Dorar jal, Kuchrung jal
- **Entangling gears:** Patan jal, Haran jal
- **Encircling gears:** Maha jal, Dal jal, Chat jal, Ghuran jal, Jhaki jal, Rekh jal, Tana jal.
- **Miscellaneous types of gears:** Arar jal, Fal jal, Impoundment, Without bailing vessel (locally called 'Debli'), Dhagamara

Analysis of the operation of fishing gears in Sone Beel: Of the 24 categories of fishing gears recorded in Sone Beel, all but Pelain could be regarded as belonging to commercial types. Notwithstanding the above, seasonality in operation of some of the types of gears is of special significance. The monsoon varieties include the Chhat jal, Dorar jal, Haran jal, Maha jal and the Tana jal. On the other hand, Kupa barshi, Tanga barshi, Gui, Paran, Dal jal, Rekh jal, Arar jal and Fal jal are the gears which are operated mainly during the winter. Dheki jal, Chat jal and Ghuran jal are seen in operation during both monsoon and dry seasons. Indeed, the Lar barshi, Dori, Pelain, Kuchrung jal, Patan jal and Jhaki jal has no seasonality and are found in use throughout the year. Analysis of efficacy of the encircling gears through CPGH, reveals that Jhaki jal seems to be by far the most efficacious encircling gear. The table also reflects highly significant differences between the different kinds of encircling gears with regard to their CPGH. Efficacy of the Jhaki jal is also reflected from its high HC value. On the other hand, analysis of MI portrayed that, Maha jal possesses the highest value of MI. (Kar and Dey, 1993; Kar, 2013).

Fishermen in Sone Beel: Fishermen belonging to 4 principal communities have been recorded in the 39 villages around Sone Beel (Kar, 1990, 2013). These are the 'Kaibarta', the 'Patni', the 'Maimal' and the 'Namasudra'. Briefly, the three categories of fishermen are:

- Occasional fishermen: They take recourse to fishing only when an occasion arises or when the situation compels. Such category of fishermen are prevalent in Sone Beel generally during the dry days when the fishing sites are easily accessible on foot.
- Part-time fishermen: This non-nomadic group of fishermen constitute *c* 15 % of

the fisherfolk population of Sone Beel. They fish only during part of a year and consider this activity as equal to or inferior to other activities of the group.

- Professional fishermen: This is the largest group among the fishing communities in Sone Beel constituting *c* 70 % of the total fishermen population around the Beel. Both poor and rich fishermen belong to this group. They fish throughout the year with the help of diverse types of fishing gears and devices without any restriction or reservation of fishing sites.

The fishing villages: About 1 Lakh fishermen live in 39 villages around shoreline of Sone Beel.

Socio-economics of the fisherfolk: The fishermen of Sone Beel have been struggling against poverty since a couple of decades. In view of the nature of economic constraints faced by the fishermen, it is strongly felt that, elimination of unscrupulous middlemen by organizing credit facilities, marketing of product and purchase of domestic as well as production requirements through Co-operatives would go a long way in the emancipation of the fisherfolk. Further, encouragement of IMC culture in the confined 'bundhs' at the DSL of the Beel could lead to a potential IMC fishery. Concomitantly, fast conveyance of the catch from the fishing centres to the fish landing stations and the urban markets would accelerate fish trade. Provision of cold storage facilities in the landing stations and the urban markets would be an added advantage to prevent loss of flesh due to decay. Moreover, popularization of the recent fish culturing and fishing techniques; and, proper rehabilitation of the fishermen could enable them to give up nomadism and paddy cultivation in the event of hardship and help gear up the upliftment of the anglers in the long run (Dey and Kar, 1989 c; Kar, 2007, 2010, 2013).

FISHING CENTRES

In Sone Beel: During the rainy season, the entire water spread area of the Beel is used for intensive fishing at both domestic and commercial scales. However, at DSL, when the water spread area of the Beel shrinks, and the Beel becomes shallow, intensive fishing activities are restricted mainly to eight distinct deeper 'Fishing Centres', which are locally called 'Bundhs'. Every year, at DSL of the Beel, these `Bundhs' are leased out principally to the Kaibarta fishermen living around the Beel, who fish in the 'Bundhs' mostly during the period November to April. Such Bundhs, lying at deeper portions of the Beel at DSL, are generally kept encircled with bamboo mat (locally called 'Khati bundh'), of height varying from 2.0-8.0 m; and, fishes are captured and marketed regularly, as required, during the entire period of operation.

The names of such 'Bundhs', with their Fishing Areas (FA), Months of Operation (MO) and Water Level (WL) as recorded at the site during the period of operation, are listed below:

Bundh	FA (ha)	MO	WL (m)
Belala	1.12	Aug-Apr	0.10-4.00
Chirakhaora	48.50	Nov-Apr	0.10-2.00
Nunail	6.50	Sep-Nov	2.00 -4.00
Putighat	2.00	Nov-Apr	0.10-2.00
Kurerkata	15.05	Dec-Mar	0.25-1.50
Kanagajar	50.00	Oct-Dec	1.50-3.00
Baroitila	105.90	Nov-Apr	0.10-2.00
Vashankuri	8.46	Dec-Mar	0.25-1.50

The 'Bundhs' witness rich harvest, particularly, on 'Paush Sangkranti' ('Pongol') Eve, when fishing goes on almost for the whole night in festive mood.

Management aspects of Sone Beel: A Case Study

We go for management of the Sone Beel Wetland, Wise use and co-operative management may also lead to long time sustainability of the wetland. Here is an exercise proposed and practiced by us on a pilot scale.

1. At DSL (Nov-Apr), Sone Beel has 8 deep 'Fishing Centres' ('Bundhs'), 5 to 200 ha, 1 to 1.75 m depth.
2. Now, only 'capture' fishing goes-on in bundhs.
3. Pisciculture would enhance FY, generate jobs & income, check exodus and conserve 'Fishermen' as 'Fishermen'.
4. Part of cultured fish be sold as earning, rest be released into Beel to replenish stock.
5. Only thing is that the Sone Beel has to be leased-out to the SB Co-op Soc which can further earn through tolls @
   (a) Rs 1.00/kg caught by per fisherman
   (b) Rs 2.00/kg bought by per fish trader

This regulated fish catch and purchase will stop over-exploitation.

Significantly:

6. Siltation control by check dams, encroachment control by 'Patta' and 'EUS' be controlled

The gist of a Model is given below:

1. The Sone Beel Fishermens' Co-operative Society (SBFCS) earns from Lessee, Fish Traders and Fishermen. It is, say @ 10 %, Rs.2.00/kg and Rs.1.00/kg respectively.

(A)If the management of Sone Beel is Lessee-centric:

2. The Lessee employs labours . He will incur some amount of expenditure in Labour employment. Study showed, it could be Rs.1,80,000.00
3. The Lessee makes other expenditure in the Beel in the form of feeding, seeding etc. : Study showed, it could be Rs.21,08,500.00
4. The Lessee earns by selling fishes to the Fishermen, say @ Rs. 500.00/kg: Study showed, it could be Rs.28,05,000.00

Study showed, Lessee's profit could be Rs 5.16,500.00

5. Expenditure-Income of all the Bundhs by the Lessee could be calculated.

(B)If the Management of Sone Beel is Co-operative Society-centric:

6. Likewise, as above, The SBFCS employs labours . It will incur some amount of expenditure in Labour employment . Study showed, it could be Rs.1,80,000.00
7. The SBFCS makes other expenditure in the Beel in the form of feeding, seeding etc. Study showed, it could be Rs.30,30,000.00 Thus, the total expenditure of the Co-op Soc , Study showed, was Rs.32,10,000.00, as the study showed.
8. The SBFCS earns by selling fishes to the Fishermen, but @ Rs 150.00/kg; and not @ Rs.500.00/kg as done by the Lessee. Study showed, it could be Rs.1,45,50,000.00

Study showed, total income of Co-op Soc could be : Rs1,45,50,000.00.
Study showed, the profit of Co-op Soc could be Rs. 1,13,40,000.00

9. The Fishermen, in turn, sell the fishes to the people in the market, say, @ Rs. 500.00/kg. Study showed, total earning could be Rs. it could be Rs.4,36,50,000.00; where as, the Fishermen, in total, had spent Rs. 1,45,50,000.00 in buying fishes from the Co-op Soc. Thus, the net profit of the Fishermen could be Rs.3,23,10,000.00. Thus, Net profit per Fisherman, the study showed, could be =Rs 3,231.00
10. Expenditure-Income of all the Bundhs by the SBFCS could be calculated, as indicated above.
11. The Expenditure-Income (of all the Bundhs)of all the Fishermen could also be calculated, as indicated above
12. Consequently, income per fisherman may also be calculated.

Siltation problem and future of Sone Beel

1. An average of 350 mg/l of silt is deposited into Sone Beel per two years, *i.e.*, 175 mg of silt/ year is deposited into Sone Beel.
2. Therefore, 17769.50 x 10^{12} mg of silt is supposed to be deposited into 101.54 x 10^{6} m^3 gross volume of Sone Beel.
3. Since, 17769.50 x 10^{12} mg of silt is supposed to be deposited into 101.54 x 10^{6} m^3 gross volume of Sone Beel; therefore, 57 years may be required for Sone Beel to be converted completely into land, considering 1980 as the base year.

The above calculation is based on the following justification:

(a) Considering 10 mg x 10 mg x 10 mg (10 mg^3) of silt may be deposited into 1 cm x 1 cm x 1 cm 1 cm (1 cm^3) of the Beel bottom, a ratio of 101.54 x 10^{15} and 17769.50 x 10^{12} has been taken and found as 5.7142 . Multiplying this number with 10 (as factor), we get 57 years (approx.) for Sone Beel to be converted completely into a mass of land.

A Vivid example of Wetland shrinkage: Change detection of Sone Beel: 1880-1980-2006

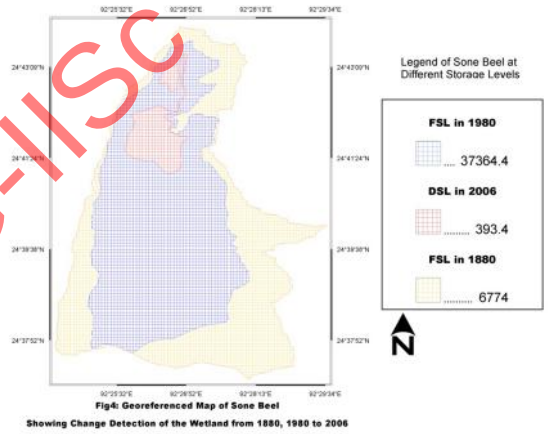

Fig4: Georeferenced Map of Sone Beel
Showing Change Detection of the Wetland from 1880, 1980 to 2006

- Worked on GIS Platform
- Compared Ground map at FSL of Kar (1980) with Geo-referenced SOI topomap (1910).
- Superimposed LISS IV (2006) Satellite imageries.
- Orange coloured region depicts FSL(1880), as 6774 ha
- Blue colour indicates FSL(1980), as 3234.4 ha
- Red colour region portrays DSL(2006), as 392.4 ha
- **Hence, within a span of 100 years, there is shrinkage of 3539.6 ha of water area in Sone Beel.**

- Deforestation, coupled with soil erosion led to very large-scale siltation causing this shrinkage.
- One can expect further diminution of water area, if siltation continues.
- Similar calculations could be carried out with other wetlands as well, to indicate the possible shrinkage in their water-spread area.

Water-use or Use of water-spread area of the lentic bodies in Assam, indicate `Fishing as the principal activity covering a big portion of the water area available in the province.'

Habitat Suitability Index (HSI): Calculation of HSI indicated that Sone Beel is neither very suitable nor very much unsuitable for Fishes, so far as the physico-chemical conditions of water is concerned.. Other information also point towards the oligotrophic condition of the wetland.

Principal Component Analysis (PCA): It also portrays absence of significant correlation among variables.

MANAGEMENT AND CONSERVATION OF FISH HABITAT AND FISHES : A CASE STUDY IN SONE BEEL IN ASSAM

In view of 'fish' being the principal aquatic animal resource and staple food of the region, and the burgeoning demand for good quality and higher quantities of fish for the health-conscious people, efforts are being made towards sustaining these enormous freshwater habitats, such as, the Sone Beel, and their bioresources. However, there are certain forms of environmental pressures which adversely affect fish, such as, habitat loss, water contamination, drought, competition, predation, fishing pressure and disease, which must be tackled to achieve sustainable growth of fish, which is a pre-requisite for formulating effective management strategies and conservation (Kar et al., 1996).

Impact of habitat loss and topographical changes: The construction of embankments and roads along Sone Beel often destroys shoreline habitats, resulting in sedimentation which spoils large quantities of fish eggs and also increases turbidity. Under such circumstances, molluscs, such as, mussels can neither feed nor easily settle at the sediment-clogged wetland bottom; and, thus, could contribute less to the food chain. Furthermore, the IMCs and the Indian shad (*Hilsa (Tenualosa)ilisha)* have been losing habitats due to the construction of the `blind dam' in the River Kachua and diversification of the waterways; thus, registering a sharp decline in their population in the Beel (Kar, 1990). Prior to 1951, the river Kachua used to flow wild and free from the Sone Beel before emptying itself into the River Kushiara. Both *Hilsa* (Dey and Kar, 1989 b; Kar, 2007, 2010) and the IMCs (Kar and Dey, 2000; Kar, 2007, 2010) used to migrate long distances from Bangladesh to enter directly into the breeding grounds in Sone Beel. The blind dam in Kachua (constructed in 1951) was replaced by a 'lockgate' in 1964; and, the main outflow has since been diverted through the River Khagra. In addition, diversification of both the major inflow and the outflow through a network of channels within the wetland has recently become a common practice in Sone Beel, mainly for agricultural purposes. Consequently, unless fish ladders, fish elevators, etc., are provided in the dams and lockgates, the long term future of the depleting fish species is not optimistic because the migration paths have been seriously disrupted. The impact of offsite erosion on the Beel fisheries is also very serious (La Roe, 1986).

Contamination of the Beel water: Sone Beel receives a large amount of organic load in the form of sewage disposal which occasionally results in depletion of the DO in some sections

of the Beel (Dey and Kar, 1987;Kar, 1990, 2007, 2010, 2013). Although pesticides are applied to the paddy cultivation at the draw-down level of the Beel, there is no potential threat of industrial pollution just now, in view of the absence of any big industry around the Beel. As such, incidents of 'direct fish kills' due to drastic reduction of DO level, shifts in fish species (Wheeler, 1979), and the occurrence of fish with cancers that have been recorded in freshwater bodies elsewhere (Klee, 1991) have not been seen in Sone Beel (Kar and Dey, 1987; Kar, 2007, 2010, 2013).

Effects of drought: Sometimes Sone faces prolonged periods of drought. In early 1979, the water level of the Beel was so low that, the spawning ground of the larger sized fishes were practically non-existent. Also, occasional high water temperatures could reduce the production of minor carps (Dey and Kar, 1990; Kar, 2013).

Competition and predation: Introduction of exotic fish may be done only after examining the possible impact they might have on the autochthonous fish species of the Beel. The introduction of *Cyprinus carpio* in Sone resulted in a substantive depletion of the population of endemic species by competition, predation or hybridization (Moyle, 1976; Kar, 2013), although, such a practice has been suggested to be useful elsewhere.

Fishing pressure: Overfishing has been exerting heavy pressure on the Beel's resources, with fishing operations carried out throughout the year. Both the quality of the fishing gears and the frequency of fishing operations be regulated.

Remedial measures: Sone Beel and its channels and associated rivers historically have been used for recreational and commercial fishing, navigation, mass transport, colonization, agricultural irrigation, water supply, and waste disposal (Kar, 1990; 2013). Therefore, in order to ensure a balanced development of the biota, and maintain the maximum sustained yield, the Beel habitat might be altered to increase the competitive advantage of desirable speices; and, more importantly, to increase the total carrying capacity for maximum fish biomass production. In order to achieve positive effects through habitat manipulation, possible measures include: alteration of land, water and vegetation; habitat construction; and, biotic manipulation (Owen, 1985; Kar, 2013).

Alteration of land: This procedure covers many aspects. Primarily, the Beel shore and stream bank erosion could be stabilized through afforestation. Rock deflectors could be built to direct stream currents. Artificial spawning sites, which have been found to be useful elsewhere (Cooper, 1980), could be created with sand, gravel or nylon mats in those portions of the Beel which are heavily mud-laden and do not serve as suitable natural spawning grounds.

Alteration of Beel water: This is a difficult task for an enormous Beel like Sone Beel. However, attempts could be made in this direction by controlling the water level, turbidity, aeration and fertility. Manipulation of the water level would be useful in controlling vegetation and spawning; and, would, thus, affect predation. It could also be an effective way for eliminating undesirable species by lowering the water level to expose and isolate their eggs (Noble, 1980). Furthermore, when the prey species become over-abundant, lowering the water level could bring them out from the aquatic vegetation which serves as their cover; thus, making them more susceptible to predators.

Turbidity: Turbidity is a menacing problem in this region and Sone Beel is subject to prolonged turbidity, both during monsoon (Dey and Kar, 1987, 2013) and dry seasons (Kar et al., 1994; Kar, 2013). The latter is due to vigorous fishing at low water levels. Reasonably clear water is a prerequisite for the healthy growth of biota, notably the fishes. Methods to reduce turbidity include, among others, the following: (i)By directly adding green or dry organic matter to the Beel; which, after decomposing, causes the

particles in the water to precipitate; (ii)by establishing herbs on the Beel-bottom at DSL; and, (iii)adding alum or gypsum to the Beel water.

Nutrients: Nutrients are an important factors in fish health; but, Sone Beel is oligotrophic (Hutchnison, 1967) with a low nutrient staus (Kar, 1990, 2013) which could be due to the characteristics of the surrounding watershed (Klee, 1991). The deficit could be improved by directly adding organic fertilizers to the Beel water; thereby, boosting phytoplankton production. Inorganic agricultural fertilizers may also be used; but, with caution against too heavy doses which could lead to the fish being killed by phytoplankton bloom. Such measures have only met with limited success elsewhere (Klee, 1991).

Vegetation management: Sone Beel has a rich flora of aquatic macrophytes (AM) (Dey and Kar, 1989 a; Kar, 2013) which provide a higher biomass during the dry season than during the monsoon. The AM are a source of oxygen, provide cover for the young fish from predators, and serve as a surface on which food organisms could attach themselves and grow. However, excess vegetational growth in the Beel could be harmful to the fishery, if it upsets the predator-prey relationship, and often leads to the stunning of fish growth due to over-population (Kar and Dey, 1992; Kar, 2013). Concomitantly, a low phytoplankton biomass in the Beel could also be due to less nutrients being made available to them due to excessive vegetational growth (Dey and Kar, 1994; Kar, 2013). Elimination of excess of AM is essential and could be done mechanically by manipulating the water level and by the use of various types of cutting machines. The harvested vegetation could be used as a soil additive in the form of compost (Henderson and Markland, 1987). Spraying or dusting of algicides, herbicides and pesticides on the Beel water could be tested to chemically control the growth of AM; but, repeated doses may prove disastrous by resulting in fish kills due to low DO and copper toxicity. Biological control of AM growth in Sone could be attempted through the introduction of herbivorous fishes which would control a variety of weeds without interfering with other fish species. The ideal species which would be closest in meeting these requirements are the grass carps and the tilapia.

Biotic manipulation: Manipulating the fish population in the wetland could be done by controlling predators, competitors, and through artificial propagation. Sone Beel harbours a rich population of cormorants, herons and cranes which help keep the fish population from exceeding the carrying capacity of the Beel. Thinning their population would likely to increase the population of both desirable and undesirable species of fish. Non-game fish species which are often considered useless (e.g., *Chanda baculis, c. nama, Badis badis, Lepidocephalus guntea* and *Danio devario*) may be removed by large-scale seine net operations and the Beel re-stocked with more desirable species. However, seining may endanger rare native species; thus, reducing the Biodiversity and overall richness of the Beel ecosystem. Artificial propagation involves the stocking, aquaculture and breeding of pollution-resistant fish. Sone Beel has 8 prominent fishing centres where intensive aquaculture could be practiced through polyculture and other techniques for raising fry and fingerlings of desired species in hatcheries for future stocking of the Beel.

Habitat construction: In addition to improving the existing habitat of the Beel, ponds and small reservoirs could be constructed adjacent to the Beel, conforming to standard specifications with proper management procedures for maintaining the fish stocks (Owen, 1985). This could release fishing pressure in the Beel.

Aquaculture and Agriculture: In order to reduce capital investment, attempts are now

being made to combine aquaculture with agriculture. An example of this being practiced in Sone Beel and its environs, particularly, at DSL, is the paddy-cum-fish culture, which results in high yields of both fish and rice.

Fish Disease: Despite the high biotic potential of the fishes of Sone Beel, there have been heavy mortalities, since 1988, affecting about 70 % of the fish population. The cause is a hitherto unknown fish epidemic, called the Epizootic Ulcerative Syndrome (EUS).

Conservation: A hardline approach to the management and conservation of the aquatic resources of Sone Beel is to impose bans or restrictions on angling activities, such as, closing a specific area to fishing, forbidding fishing during a particular season, restricting the number or size of fishes caught, restricting the types of fishing gears, promoting aquacultural practices and supporting State and National regulations protecting a particular endangered species. While imposing restrictions, it is essential to be adaptable and take into consideration the full spetrum of the users of the resource. Concomitant to administrative restrictions, encouraging results could be obtained through mass education of the Beel-users (particularly, the fisherfolk) by the NGOs regarding rational harvest and conservation and management of the Beel resources. The potential health hazard posed to the Beel fishes by EUS is to be tackled through regular monitoring of the Beel environment and fish health; and, by adopting quarantine measures.

CONCLUSION

It is now gradually being realized that, many of the management techniques would not be required, if fishery habitats were properly protected; and, that, priority be given to finding ways to prevent the problems from occurring in the first place, rather than relying on quick-fix solutions. Beel and stream improvement programmes could now begin to focus on the entire human-land relationship within a watershed. Financial incentives could be offered which would encourage farmers to practice good soil and water resource management. These are some of the notable problems which need to be addressed in order to find a lasting solution.

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