FISH DIVERSITY AND CONSERVATION ASPECTS IN AN AQUATIC ECOSYSTEM IN NORTHEASTERN INDIA

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ABSTRACT

Biodiversity and its conservation are regarded as one of the major issues of enabling sustainable use of natural resources. This contribution focuses on the diversity of fish population and their conservation aspects in the biggest freshwater tectonic Lake Sone (3458.12ha) in Assam, India. The study revealed the occurrence of 69 species of fishes in the lake belonging to 49 genera, 24 families and 11 orders. Of these fishes, 84.2% belonged to the primary freshwater group (Cyprinids 35.39%), while the rest to the peripheral class Attempts have been made to portray the fish diversity of the lake zoogeographically and emphasise the value of conserving biodiversity. Further, results of linear regression revealed significant correlations between fish yield and soil organic carbon, soil potassium, water pH total alkalinity and conductivity, and aquatic macrophytic biomass.

KEYWORDS

Aquatic ecosystem, Assam, conservation, fish diversity, fish yield, Lake Sone, threats

Ichthyodiversity refers to variety of fish species; depending on context and scale, it could refer to alleles or genotypes within piscian population, to species of life forms within a fish community, and to species or life forms across aquaregimes (Burton *et al.*, 1992). Biodiversity is also essential for stabilization of ecosystems, protection of overall environmental quality, for understanding intrinsic worth of all species on the earth (Ehrlich & Wilson, 1991) Positive correlations between biomass production and species abundance have been recorded in various earlier studies (Nikolsky, 1978). The species diversity of an ecosystem is often related to the amount of living and nonliving organic matter present in it. However, apparently, species diversity depends less on the characteristics of a single ecosystem than on the interactions between ecosystems, e.g., transport of living animals across the different gradient zones in the waterbody. The effect of such transport is an important 'information' exchange enhancing the genetic diversity. The genetic imprinting of various populations of lentic fish species is essential since the freshwater ecosystems constitute crucial parts of their life-support systems by providing nursing grounds and feeding areas (Hammer *et al.*, 1993). Further, species diversity is a property at the population level while the functional diversity concept is more strongly related to ecosystem stability and stresses, physical and chemical factors for determining population dynamics in the lentic ecosystem. Also, the various organisms including the plankton play a significant role in the dynamics of the ecosystem (Kar & Barbhuiya, 2004).

Fish constitutes almost half of the total number of vertebrates in the world. They live in almost all conceivable aquatic habitats; *c.* 21,723 living species of fish have been recorded out of 39,900 species of vertebrates (Jayaram, 1999) Of these, 8,411 are freshwater species and 11,650 are marine India is one of the megabiodiversity countries in the world and occupies the ninth position in terms of freshwater megabiodiversity (Mittermeier & Mittermeier, 1997). In India, there are *c.* 2,500 species of fishes; of which, *c.* 930 live in freshwater and *c.* 1570 are marine (Kar, 2003a). This bewildering ichthyodiversity of this region has been attracting many ichthyologists both from India and abroad. Concomitantly, the northeastern region of India was identified as a biodiversity hotspot by the World Conservation Monitoring Centre (WCMC, 1998). This rich diversity of this region could be assigned to certain reasons, notably, the geomorphology and the tectonics of this zone. The hills and the undulating valleys of this area gives rise to large number of torrential hill streams, which lead to big rivers; and, finally, become part of the Ganga-Brahmaputra-Barak-Chindwin-Kolodyne-Gomati-Meghna system (Kar, 2005c).

Based on IUCN categories, the CAMP Workshop (Molur & Walker, 1998) for freshwater fishes identified certain fish species which have attained the threatened/endangered status. At the same time, there has been little study with regard to details of endemism and species richness in northeastern India As such, a detailed study related to germplasm inventory, evaluation and gene banking of freshwater fishes would not only help us to land at a concrete decision on the above-mentioned aspects; but, would also contribute to fulfilling India's obligation to CBD with special emphasis on Articles 6 and 8 (UNEP, 1992). Further, development of database on the biological parameters is a pre-requisite for preparation of detailed fish inventory. Genetic characterization and gene banking is a step forward towards further confirmation of the species at the molecular level

Fish catches have always been fluctuating widely (Bertram,

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1985; Kar, 2000). From an estimated 500million ha of inland waters in the world, the estimated total catch of fish is *c.* 7.0 million metric tonnes (mt) per annum. This excludes the catch of subsistence and sports fishermen. In many Asian countries, inland catches make up 40-70% of the total fish production (FAO, 1986).

There have been extensive studies on the Freshwater fishes of India, notably by, Hamilton (1822); Shaw and Shebbeare (1937); Hora (1921a,b, 1930, 1937, 1939, 1940, 1943, 1951, 1953); Misra (1959); Menon (1974, 1999); Dey (1973); Jayaram (1981, 1999); Sen (1982); Sen (1985); Talwar and Jhingran (1991); Nath and Dey (1999, 2000); Dey and Kar (1989a,b,c, 1990); Kar and Dey (1986, 2000, 2002); Kar and Barbhuiya (2000a,b; 2004); Kar *et al.* (2002a,b,c, 2003, 2004); Kar (1984, 1990, 2003a,b, 2004, 2005a,b,c,d,e). But most of them are concerned with taxonomy, biology and aquaculture.

However, inspite of tremendous significance in determining productivity and calculating species diversity, not many studies have been done on the fish population dynamics, ichthyodiversity and conservation of fishes in the lentic ecosystems in northeastern India in particular (Kar *et al.*, 2003) as compared to elsewhere in India (Jhingran & Tripathi, 1969) and the world (Janzen, 1981).

The icthyofauna of the northeastern region of India has elements of the Indo-Gangetic region; and to a some extent, of the Myanmarese and South-Chinese regions (Yadava & Chandra, 1994). Ghosh and Lipton (1982) had reported 172 species of fishes with reference to their economic importance while Sen (1985) reported 187 species of fishes from Assam and its environs. Sinha (1994) compiled a list of 230 species of fishes from northeastern India. Nevertheless, Nath and Dey (1997) recorded 131 species of fishes from the drainages in Arunachal Pradesh alone. Further, according to Sen (2000), of the *c.* 806 speices of fishes inhabiting the freshwaters of India (Talwar & Jhingran, 1991), the northeastern region of India is represented by 267 species belonging to 114 genera under 38 families and 10 orders. This is *c.* 33.13% of the total Indian freshwater fish species. Of the 267 species, Cypriniformes dominates with *c.* 145 species followed by Siluriformes (72), Perciformes (31), Clupeiformes (7), Anguilliformes (3), Cyprinodontiformes (3), Osteoglossiformes (2), Synbranchiformes (2), Syngnathiformes (1) and Tetraodontiformes (1). Kar (2003a) reported the occurrence of 133 species of fishes through a pilot survey conducted in 19 rivers spread in Barak drainage (Assam), Mizoram and Tripura. Kar (2005a), further, reported the occurrence of 103 species of fishes through an extensive survey conducted in six principal rivers in Barak valley (Assam), Mizoram and Tripura.

The province of Assam is gifted with a myriad of riverine and tectonic lakes (locally called beels), which alone constitute *c.* 81% of the total lentic area (>1,20,000ha) in Assam. In Assam, there are *c.* 1,392 beels covering an area of *c.* 70,000ha; of which, *c.* 19,000ha is in good condition, *c.* 16,000ha is in semi-derelict condition and the remaining *c.* 35,000ha is in derelict condition (Kar *et al.*, 1996).

Information on the interaction between hydrobiological conditions and fish yield in any waterbody is of prime importance before endeavouring to utilize it as a productive fishery. Limnological and watershed parameters, such as water temperature (WT), turbidity (t), water pH (WpH), dissolved oxygen (DO), free carbon di-oxide (FCO_2), total alkalinity (TA), water conductivity (WC), soil temperature (ST), soil pH (SpH), soil organic carbon (SOC), soil phosphorus (SP), soil potassium (SK), and aquatic macrophytic biomass (AMB) have significant role on fish yield in a lake ecosystem. As such, interaction of these parameters with respect to fish yield (FY) of Lake Sone in forms one of the principal objectives of the present study and this paper attempts to reveal the extent of interaction of these factors in the present biotope.

Study Area

Lake Sone or Sone Beel (as it is locally called) is the largest freshwater tectonic lake of Assam having a waterspread area of 3458.12ha at the full storage level (FSL), while it shrinks to 409.37ha at the dead storage level (DSL). The Beel has maximum length and breadth of 13.2km and 4.2km, respectively. It has a shoreline of 35.4km. The Beel is a syncline near the Badarpur line of folding and the Chargola anticline. It belongs to the Mio-Pliocene with mostly alluvium in the beel-bed and fine grain sandstones in the catchment which also has tropical evergreen forest. The Sone Beel is continuously fed by the major inlet called Singla which originates as Thing Tlawng Lui from the Mizo Hills (alt. 365m) and traversing a tortuous course of *c.* 62km, it enters Sone Beel. The major outlet, river Kachua, drains the lake water into the bigger river called Kushiara, after traversing a distance of *c.* 19km from the northernmost end of the lake (Kar, 1990).

Methodology

Sampling and data collection were done for two years (Jan 2002-Dec 2003). Thirteen independent variables were estimated encompassing physico-chemical characteristics of water, soil and aquatic macrophytic biomass. Sampling was done at fortnightly intervals for all these limnological characteristics. The water quality parameters included water temperature (WT), turbidity (t), water pH (WpH), dissolved oxygen (DO), free carbon di-oxide (FCO_2), total alkalinity (TA) and water conductivity (WC) and were studied through standard methods (APHA, 1995). The soil characteristics included soil temperature (ST), soil pH (SpH), soil organic carbon (SOC), soil phosphorus (SP) and soil potassium (SK) and were studied after Jackson (1973). The aquatic macrophytic biomass (AMB) was studied through standard procedure (Dey & Kar, 1989a; Kar, 2005e) and identified after authoritative sources, like BSI (personal communication) and literature (Biswas & Calder, 1984). The data on annual fish yield have been extrapolated from daily catch statistics recorded at all the landing stations of the Beel (FAO, 1974) while the trend, population dynamics and cyclic variations have been constructed on the 12-month moving average method (Coxton & Cowden, 1950).

Diversity encompasses two different concepts of variety and variability, *viz*., richness and evenness These two concepts, in theory, could be applied across a hierarchy of scales, from genetic diversity through to ecosystem diversity (Burton *et al*, 1992). In the present study, diversity has been measured by the number of species (species richness) and by using the two indices, *viz*., Shannon-Weaver (H') and Simpson's (D) indices These are given by:

(a) Shannon-Weaver index of diversity (Shannon & Weaver, 1949; Wolda, 1983):

$$H' = -\Sigma p_i \ln p_i$$

where, p_i is the proportion of the i^{th} species in the sample. The samples were collected from a large fish community, in which, the total number of species is known.

(b) Simpson's index of diversity (Simpson, 1949)

$$D = 1 - (\Sigma p_i^2)$$

Twenty-five different equations (both linear and quadratic relationships) were analysed and the best relationship was selected based on strong correlation co-efficient and least percentage of standard error of Y estimate (dependent variable) Finally, the step-wise forward selection method was used in a linear multiple regression of fish yield (FY) against the independent variables The step-wise procedure made no allowance for the possibility that a variable entered as significant might become insignificant on the addition of further variables into the equation, and a variable entered into regression equation and subsequently removed (after addition of several other variables) would indicate that the variable is significant in reducing the variation. The final regression, thus, indicates only significant ($p < 0.05$) variables.

Results and Discussion

Fish diversity

Sixty-nine ichthyospecies belonging to 49 genera, 24 families and 11 orders have been recorded in Lake Sone (Table 1). Of these, 84.2% belong to the primary freshwater group, while the rest to the peripheral class On the basis of Indian and extra-Indian territorial distribution, the fish species of Sone include 20 widely distributed species and eight species of northern India. Further, ecomorphologically, the true rheophilic group contains only one species while the semi-torrential group includes five species. The migratory class contains seven species and the plainwater group includes 57 species found in the lake. Population dynamics of the Indian major carps (IMC), clupeids, silurids and bagrids have been dealt with in this paper due to their commercial importance and significant contribution to overall fish production of the lake.

The population of IMC, as a group, fluctuated with a single peak in December of the first session; and, with two peaks, one each in September and January during the second. The rich landing during the dry season is essentially due to high catch

Table 1. Fish Diversity in Sone Beel of Assam. 69 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* (LA)	36. *Rita rita* (MA)
2 *Gudusia chapra* (R)	37 *Ompok bimaculatus* (LA)
3. *Hilsa* (*Tenualosa*) *ilisha* (LA)	38 *Wallago attu* (A)
4 *Chitala chitala* (R)	39 *Ailia coila* (LA)
5. *Notopterus notopterus* (MA)	40. *Clupisoma atherinoides* (MA)
6 *Amblypharyngodon mola* (A)	41. *Clupisoma garua* (MA)
7 *Aspidoparia morar* (R)	42 *Eutropiichthys vacha* (MA)
8 *Barilius bendelisis* (VR)	43. *Silonia silondia* (R)
9. *Catla catla* (LA)	44. *Pangasius pangasius* (R)
10. *Cirrhinus mrigala* (MA)	45. *Gagata nangra* (R)
11. *Cirrhinus reba* (MA)	46. *Glyptothorax telchitta* (R)
12. *Cyprinus carpio* (A)	47. *Clarias batrachus* (MA)
13. *Danio devario* (LA)	48. *Heteropneustes fossilis* (A)
14 *Esomus danricus* (LA)	49. *Chaca chaca* (R)
15 *Labeo bata* (R)	50. *Xenentodon cancila* (A)
16 *Labeo calbasu* (MA)	51 *Aplocheilus panchax* (A)
17 *Labeo gonius* (LA)	52. *Channa gachua* (A)
18. *Labeo nandina* (R)	53. *Channa marulius* (R)
19 *Labeo rohita* (LA)	54. *Channa punctatus* (A)
20. *Puntius chola* (A)	55. *Channa striata* (A)
21 *Puntius conchonius* (A)	56 *Amphipnous cuchia* (MA)
22. *Puntius sarana sarana* (R)	57. *Parambassis baculis* (A)
23. *Puntius ticto* (A)	58. *Chanda nama* (A)
24 *Rasbora daniconius* (LA)	59. *Badis badis* (A)
25. *Rasbora elanga* (R)	60. *Nandus nandus* (LA)
26. *Salmostoma bacaila* (LA)	61 *Rhinomugil corsula* (LA)
27 *Botia dario* (A)	62. *Sicamugil cascasia* (LA)
28. *Lepidocephalus guntea* (A)	63. *Glossogobius giuris* (A)
29 *Acanthocobitis botia* (R)	64. *Anabas testudineus* (A)
30 *Somileptes gongota* (LA)	65 *Colisa fasciatus* (MA)
31 *Mystus cavasius* (R)	66. *Macrognathus aral* (A)
32 *Mystus corsula* (LA)	67 *Macrognathus pancalus* (A)
33. *Mystus tengara* (LA)	68 *Mastacembelus armatus* (A)
34 *Mystus vittatus* (A)	69. *Tetraodon cutcutia* (R)
35. *Aorichthys seenghala* (MA)	

A - Abundant; LA - Less Abundant; MA - Moderately Abundant; R - Rare; VR - Very Rare

at low water level (WL) and the monsoon influx could be due to more IMC migration into the lake from the adjoining rivers. *Puntius chola*, among the minnows, depicted rich landing from the lake; thus, contributing significantly to the total fish production.

The clupeids of the lake consisted of *Hilsa* (*Tenualosa*) *ilisha* and *Gudusia chapra* Population dynamics of the group behaved uniformly during both the seasons. The seasonal fluctuation of the group is essentially due to *G. chapra* Hilsa is an anadromous migrant into Sone ecosystem during the monsoon season only unlike two (monsoon and winter) in other freshwater bodies (Kar & Dey, 1982; Dey & Kar, 1989b; Kar & Dey, 2002).

The siluroids show uniform trend in their dynamics. The bagrids, as a group, showed peaks in October and February in the first session and in August and November in the second session. *Mystus vittatus* seemed to be the most abundant fish species among the bagrids which had accounted almost entirely for the dynamics of the whole group.

Both H' and D followed almost the same pattern of fluctuation with peaks in monsoon season. Sone Beel is highly diverse during the monsoon season with a rising trend beginning from July. It has been found that, species like *P. chola, G. chapra, O. bimaculatus* and *M. vittatus* contributed significantly towards the high production from the lake during monsoon; and, there had been no sign of decreasing trend in diversity even under stressed condition (Dey & Kar, 1990). However, the decreasing trend in diversity indices during the other seasons were mainly due to competition and intense fishing

Before 1950, Sone Beel had not been subjected to much man-made disturbances and it exhibited high species diversity in a stable environment; and, possibly, because of this, there had not been evolution of finer specializations and adaptations which resulted in smaller niches and more species occupying a unit space of habitat. It could also be argued that the high diversity of lake Sone fish communities has not been achieved only by precise niche' diversification in an equilibrium community but rather by highly variable larval recruitment which causes a competition for vacant living spaces in which the first to arrive wins Since 1950, with the influx of large number of fishermen from adjoining Bangladesh (earlier East Pakistan) into Lake Sone, the biotope had turned into a disturbed environment due to tremendous fishing and agricultural activities, which have been exerting substantial influence on the fish population of the lake. Sone Beel ecosystem of today could be regarded as a disturbed ecosytem; but, at the same time, it has been preserving its rich fish diversity as compared to many undisturbed ecosystem where competition and exclusion are more intense

It may be noted here that the introduction of exotic common carp (*Cyprinus carpio*) into Sone Beel, about three decades ago, might have had significant impact on the diversity of indigenous fish species of the Beel. However, information collected from the field revealed that the aim of this exercise was to transform the slow-growing fishery into a rapid one; and, also with the concomitant aim of compensating for the loss caused to the fishery of the Beel by the construction of a blind dam in river Kachua (the major outlet of the Beel) during 1950. Although the blind dam was later replaced by a lock-gate during 1964, the latter was not provided with any fish ladders and fish passes; thereby, resulting in no improvement in the situation (Kar *et al.*, 1996). These hindrances had reduced the freshwater pulse and had enough role to trigger deviation of the migratory path of the fishes to take a lengthier route in order to enter Lake Sone Moreover, a serious effect of this single species introduction led to the inability to maintain genetic diversity inherent in naturally-reproducing population

Limnology

The limnological parameters did not show much abrupt fluctuation with WT ranging from 18.7 to 32.3°C; turbidity 20.56 to 185.54 TU; WpH 6.0 to 7.9; DO 2.43 to 5.96mg/lit; FCO_2 0.90 to 14.55 mg/lit; TA 25.0 to 76.0mg/lit; WC 0.000051 to 0.000039 mhos/cm; ST 19.9 to 32.3 C; SpH 5.09 to 5.99; SOC 0.25 to 1.74%; AP 0.15 to 1.93mg/100g; AK 1.6 to 24.8mg/100g. The AMB varied from 0.50 to 21.90kg/m².

Fish yield trend

The average fish yield (FY) from Lake Sone has been estimated to be 96.8kg/ha. *Puntius chola* contributed to the bulk of the lake FY registering an annual relative yield (ARY) of 24.60%. The IMC depicted an average ARY of 2.94% while *Hilsa (Tenualosa) ilisha*, with an ARY of 0.04%, portrayed a single run in Lake Sone during the monsoon as against two in other Indian waters.

Regression analysis

Regression analyses of the variables SOC and FY, AMB and FY showed linear relationship as shown below:

(a) FY = 49146.34 - 22654.3 (SOC), R = 0.60 (standard error of Y estimate = 11.25%)

(b) FY = 32600.18 - 836.04 (AMB), R = 0.39 (standard error of Y estimate = 31.02%).

Analysis of the correlation between FY and some of the limnological parameters, as referred to above, were also done through quadratic equations. This reveals significant relations of FY with the parameters WpH, TA, WC, SOC, SK and AMB (based on respective correlation coefficient values). These quadratic relationships between FY and parameters, based on their respective best equations, are given below:

(i) FY vs WpH:

(a) $FY = 1/(0.11940 * (WpH + (-6.996)^2 + 0.02812)$, R = 0.486.

(b) $FY = 31.550 * e^{\wedge}((\ln(pH) - 1.931)^2/(-0.01754))$, R = 0.470.

(ii) FY vs TA:

$Y = 31.37 * e^{\wedge}((\ln(TA) - 3.922)^2/(-0.2397))$, R = 0.469.

This result shows maximum FY at a TA value of 50 and gradual decreasing yield trend at TA values both <50 and >50 corroborates with the field condition in the studied lake.

(iii) FY vs WC:

This relationship was found to be power law and is given by $Y = 40.90 * 0.9935^{\wedge} WC$, R = 0.668

indicates gradual decreasing trend in FY at high values of WC: a situation which reflects the field condition in the studied biotope.

(iv) FY vs SOC

$Y = 23.06 * SOC^{\wedge}(-1.313 * SOC)$, R = 0.713

reflects the actual condition in the field with a gradual fall of FY at higher SOC values because more SOC reveals more organic decomposition.

(v) FY vs SK

(a) $Y = (17.88 + 3.2 * SK + (-0.162) * SK * SK)$, R = 0.459

(b) $Y = 32.69 * e^{\wedge}((SK - 10.60)/2)$, R = 0.5656

portrays a gradual decreasing trend from an initial high value

(vi) FY vs AMB

$Y = 30.56 * 0.9387^{\wedge}AMB$ R = 0.578

$Y = 1/(-0.0004475 + (AMB) + (-5.946))^2 + (-0.4520)$, R = 0.848

reveals a decreasing trend of FY with higher AMB in the lake. This tallies with the field situation because more AMB would make less space available as fish habitat besides hindering their free movement

The stepwise multiple regression of limnological parameters (Table 2) indicate that the variations in FY are mostly caused by DO, WpH, t, TA and ST; while, variation in fish production due to variables, such as FCO_2, WC, SpH, SOC, SP, SK and AMB are less These analyses clearly indicate that factors, such as, factors, such as, DO, WpH, t, TA, ST and to some extent WT determines the fish yield in Lake Sone

Table 2. Stepwise regression of FY with limnological parameters

Variables X	Y	R	Probable relationship
1. WT, t, pH, DO FCO_2 TA WC	FY	0.67	Y=-117953 + 3540.548(WT) + 148 3983 (t) + 6021.701 (WpH) + 2594.402 (DO) + (-2023.06)(FCO_2) + 308 9608 (TA) + (-100 787) (WC)
2. WT, t, pH, DO FCO_2 TA WC ST	FY	0.74	Y=-183183 + (-902.896)(WT) + 182 774 (t) + 13706.11 (WpH) + 551.7775 (DO) + (-3341.24)(FCO_2) + 65.04012 (TA) + (-84 2475) (WC) + 5747 297 (ST)
3. WT, t, pH, DO, FCO_2 TA WC ST, SpH	FY	0.75	Y=-161535 + (-653.563) (WT) + 1822.5566 (t) + 15725.71 (WpH) + 1510.482 (DO) + (-2980 64)(FCO_2) + 108.1148 (TA) + (-80.7343)(WC) + 5949 46 (ST) + (-10136.6)(SpH)
4. WT, t, pH, DO, FCO_2, TA, WC ST, SpH SOC	FY	0.84	Y= -83726.4 + (-372.109)WT + (148.0) (t) + (9012.41)WpH + (1827.7)(DO) + (-3820.74)(FCO_2) + (135.77)(TA) + (-23.81)(WC) + (3674.26)(ST) + (-2300.7)(SpH) + (-23605.6)(SOC)
5. WT, t, pH, DO, FCO_2, TA, WC, ST, SpH SOC SP	FY	0.86	Y= -110407 + (1348.13)(WT) + (160.61)(t) + (15455.41)(WpH) + (2394.55)(DO) + (-3928.85)(FCO_2) + (196.46)(TA) + (-35.10)(WC) + (2795.53)(ST) + (-10424 3)(SpH) + (-18761 8)(SOC) + (-737.427)(SP)
6. WT, t, pH, DO, FCO_2, TA, WC, ST, SpH. SOC SP, SK	FY	0 87	Y = -104668 + (1886.93)(WT) + (166.34)(t) + (16153.97)(WpH) + (2573.73)(DO) + (-3636.02)(FCO_2) + (299.86)(TA) + (-33.2803)(WC) + (1838.72)(ST) + (-10532 1)(SpH) + (-20777.6)(SOC) + (-462 359)(SP) + (-630 744)(SK)
7. WT, t, pH, DO, FCO_2, TA, WC, ST, SpH SOC, SP, SK AMB	FY	0.87	Y = (-106000) + (1934.68)(WT) + (166 39)(t) + (16091.08)(WpH) + (2504.72)(DO) + (-3642.79)(FCO_2) + (300.56)(TA) + (-33.50)(WC) + 1845.32)(ST) + (-10476.7)(SpH) + (-20205.4)(SOC) + (-468 66)(SP) + (-626.79)(SK) + (- 39.34) (AMB)

Conservation

Conservation programmes help fish production to be more sustainable while at the same time maintain diversity Conserving diversity also improves the likelihood of maintaining minimal viable populations of rare and late-successional species Maintaining ichthyodiversity is important because it is not always possible to identify which individual species are critical to aquatic ecosystem's sustainability. Many fish species may provide genetic material and may serve as ecological indicators. Diversity reduces disease problems and encourages recovery from disturbance. Although, over the past billion years, adaptation and diversification had tended to increase the number of species, with the escalation of human population, their infringing into the wilderness and rapid industrialization, a decline in species diversity became noticeable. This situation is sometimes associated with the destruction of aquatic ecosystems The situation is rather in an aggravated condition in the lakes like Lake Sone situated in the tropical developing countries where the process of species extinction and genetic loss may become severe in future due to loss of habitat by siltation, blockade of the waterways, injudicious introduction of exotic fish species, irrational harvest of juveniles and large-scale prevalence of fish diseases (Kar, *et al.*, 1995; Kar, 2005b)

Fish conservation in Sone Beel may be practiced either *in situ* or *ex situ*. Methods, such as, secluding portions of the lake as 'aquareserves' with minimum viable population size in it could be practiced as *in situ* conservation strategy *Ex situ* conservation may involve preservation of the gene pool as an insurance against loss in *in situ* reserves. *In situ* is best achieved both in natural and man-made ecosystems The concept mainly revolves around the conservation of endemic species This method has the advantage of being less expensive than *ex situ* measures in the long run and also allows continued co-evolution with other species *Ex situ* approach takes care of species outside their natural habitats, especially in farms or genetic resource conservation centres. The ultimate *ex situ* measures are the gene banks where cryostorage of gametes and embryos are achieved (Kar, 2005d).

Notwithstanding the above, a number of stresses, mostly man-made, notably, day in and day out fishing operations, paddy cultivation within the lake itself, etc , have been operating on fishes in a very detrimental way; where as Lake Sone was said to be an almost stress-free environment once upon a time. As such, the obvious result of these stresses on commercial species is evident through reduced catch per unit effort. Unlike commercial species, like the IMCs, other large growing fishes (LGF) like the *Wallago attu, Aorichthys seenghala* etc., where depletion or decline of numbers is easily detectable, and some remedial measures could be taken; non-commercial species, like the *Chanda nama, Esomus danricus, Rasbora daniconius, Badis badis, Nandus nandus, etc.,* though a part of the biodiversity, may not even attract notice, even if affected by the stresses.

In addition to the above, overexploitation has been tremendously detrimental to the overall ichthyodiversity of Sone Beel. Fishes like, *Gudusia chapra. Salmostoma bacaila, Nandus nandus. Eutropiichthys vacha Ompok bimaculatus, Clupisoma garua, Alia coila Peudeutropius atherinoides,* which were abundant once upon a time (Kar, 1990), are less abundant today (Kar, 2000) Ichthyospecies like, *Chitala*

chitala, Labeo nandina, Silonia silondia and Pangasius pangasius are almost obliterated from the lake today. Even the population of the IMCs have been seriously depleted today (Kar, 2005c). In addition to vigorous fishing operations by 24 different types of fishing implements and devices (Kar & Dey, 1991, 1993, 1996; Kar *et al.*, 1998) by *c.* 1 lakh fishermen living around the Lake (Kar & Dey, 1987; Dey & Kar, 1989c, Dhar *et al.* 2004), the dreadful fish disease, called epizootic ulcerative syndrome (EUS), prevalent in the Lake and its environs, has been a serious threat to sustenance and conservation of the fishes and it has resulted and continuing to result in severe erosion of genetic variability and biodiversity (Kar & Dey, 1990a,b,c; Kar *et al.*, 1990, 1993, 1995a,b; 2003; Kar, 1999, 2004, 2005d).

Introduction of exotic fishes, as part of aquaculture for commercial gains, do result in loss of indigenous ichthyodiversity. Lake Sone did exhibit substantial depletion in the major bulk of its indigenous ichthyodenizens due to introduction of the exotic carp, *Cyprinus carpio*, into the lake by the fish traders in the fishing centres at the dead storage level of the lake with the aim of a rich harvest. Therefore, introduction of exotic fish in the freshwater lentic systems like Lake Sone should be done only after examining the possible impact it might have on the indigenous ichthyodenizens (Dey, 1981; Kar, 1990). Similarly, the indigenous fish species of Loktak lake of Manipur are being fast replaced by *C. carpio* due to its introduction for culture. Elsewhere, the displacement of *Catla catla* from many reservoirs and its associated ecological disaster has been noticed after introduction of the silver carp in Govindsagar and its neighbouring lentic bodies.

Though a number of causes have been identified, it has not been possible to totally undo the damage caused by each factor. As such, a holistic approach, integrating the concept of sustainable development and conservation measures could help improve the situation. Measures, such as, some amount of desiltation; diversion of effluents for treatment could lead to appreciable improvement in the levels of certain water quality parameters like pH, dissolved oxygen, etc., and fish yield could reveal a quantum jump within a short period of time.

Conclusion

A typical fishery in tropical waters may lead to harvest of rich diversity of ichthyospecies. Each species often consists of several local groups with a distinct genetic make-up. It could be a little difficult for detailed study of each group. There could be uncertainties with all scientific endeavours to monitor abundance and productivity of stocks and the underlying causes. Further, there are uncertainties with regard to climate, aquatic ecosystem productivity, predation and fishing pressure. Managing for ichthyodiversity provides a useful clue against these uncertainties because it represents the epitome of water stewardship, quite distinct from simply maintaining reliable stocks of individual species. Fishermen and ichthyologists have a critical role to play in understanding and protecting diverse fish resources.

Concomitant to the above, the ongoing process of ecosystem change, as is evident in lake Sone today, directly or indirectly affects the abundance and composition of the fish species; and, is, to a large and increasing degree, due to human activities which are sometimes unconnected to fisheries. Such increasing impacts of other human activities on the Sone Beel ecosystem highlights the need for a regional aquatic ecosystem approach to fisheries management including water-use patterns. The state of the fish community may be seen as a valid integrative indicator of aquatic ecosystem quality and health; and, little more distantly, may be viewed as a regional quality of life for the human beings.

Lake Sone is a vast aquaregime with rich diversity of 69 fish species. Conservation of fish diversity assumes topmost priority under the changing circumstances of gradual habitat degradation. Whether or not Sone Beel would be able to maintain its ichthyodiversity would be largely determined by the water-use patterns since fish diversity is an interdependent part of a cluster of diversities in the human society and in the aquatic ecosystem. However, in order to assure ecological and economic sustainability of the fisheries of Lake Sone, matching human activities with natural pulses of the ecosystem should be particularly stressed in management practices rather than basing such practice on an unrealistic expectation that fish populations provide a steady source of exploitation.

The average fish yield (FY) from Sone Beel has been estimated to be 96.8 kg/ha. Species, such as, *Puntius chola* contributed to the bulk of the lake fish landing registering an annual relative yield of 24.60%. The present study reveals that, in Lake Sone:

(a) maxium FY occurs in pH range of 6.9 – 7.1
(b) Fish yield declines with increase in WC, SOC and AMB
(c) The stepwise regression analysis indicate that the variations in FY are mostly caused by DO, WpH, t, TA and ST while variations in FY due to variables such as FCO_2, WC, SpH, SOC, SP, SK and AMB are less.

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