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Water is an indispensable, natural, renewable resource which is very crucial for sustenance of life on earth, so it is rightly called ‘Elixir of Life’.

The wetlands have been degrading at an alarming rate due to various natural and anthropogenic reasons. Our efforts must be directed towards conserving aquatic resources as they have an enormous aesthetic and economic value. For this purpose a baseline data can be very helpful for designing conservative measures. A review of the work done on the wetlands in India and abroad has been given below for evaluating our result in a better way.

2.1. Fish Biodiversity

Ichthyodiversity refers to a variety of fish species (Burton et al., 1992). The biodiversity of fishes mainly depend on the biotic and abiotic factors, age of water body, mean depth, water level fluctuations and bottom topography of an aquatic ecosystem.

The very first documentation on Indian fish species were done by Hamilton-Buchanan (1822). Hora (1956) made notable contributions on fish systematics which was further extended by many workers (Misra, 1962; Talwar and Jhingran, 1991). Tandon and Johal (1972) explored fish fauna of Ropar wetland, which is a highly diverse area and was considered as a Ramsar Convention Site in the year 2002 and as many as 35 species of fish were reported from Ropar wetland (Randhawa, 1990).

Jhingran (1991) and Jayaram (2010) recorded 2500 species in India out of which 930 inhabit inland water and 1570 are marine water fishes. Handa (1993) reported 17 fish species from Kanjli wetland, Punjab and a few of the common fish species were Catla catla, Channa marulius, C. striatus, Cirrhinus mrigala, Labeo calbasu and L. rohita. Johal (2005) studied biodiversity of fishes with special references to fresh water species. Kar et al. (2006) recorded fish biodiversity of an aquatic ecosystem in North-Eastern India and found 69 fish species. He further
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emphasized that there is a significant correlation between fish yield and potassium, pH, alkalinity and conductivity.

Dua and Prakash (2009) studied seven different reaches of Harike wetland to determine fish abundance and distribution. A total of 61 fish species belonging to 35 genera were reported of which Order Cypriniformes dominated. Of all fish species reported from Harike wetland, one was critically endangered, four were endangered and thirteen were vulnerable species (Molur and Walker, 1998).

Rafique (2007) assessed Rangla wetland complex (Pakistan) viz. Bheriwala lake, Rangla lake, Jarrwali lake, Kuttaywal lake and Hansewal lake for fish biodiversity and further correlated abundance of fish biodiversity with decreasing levels of salinity. A total of 24 species were found from Bheriwala lake with 4% salinity; Rangla lake with salinity 9% was found to be inhabited only by *Tilapia* which has capacity to tolerate high salinity levels and remaining wetlands with much higher salinity levels i.e. 10 – 18%, no fish species was found as high salinity levels render these lakes unhealthy and unfit for fish species.

Korai et al. (2008) studied fish biodiversity of Keenjhar Lake, Sindh, Pakistan in relation to its physico-chemical characteristics. 51 fish species were recorded, of which family Cyprinidae dominated represented by 19 species followed by family Bagridae, family Channidae, family Mastacembelidae, family Clupiuedae, family Notopteridae, family Siluridae, family Schilbeidae, family Channidae, family Nandidae, family Gobidae, family Claridae, family Heteropneustidae, family Belonidae and family Cichlidae.

According to National Bureau of Fish Genetic Resources (NBFGR) (2008), Research Advisory Committee Meeting, the total fish biodiversity of India is 2,534 which include 2,243 native species and 292 exotic ones. Verma et al. (2008) observed 39 fish species from Rana Partap Sagar Lake, Rajasthan and further calculated length-weight data of 16 commercially important fish species which was used to estimate Pondral index (an indicator for general well being of fish) and that was found to ranged between 0.93-7.5. *Catla catla, Labeo calbasu, Labeo rohita* and *Tor khudree* showed significantly high values of pondral index which indicated satisfactory growth status of these fish species in this water body.

Forty-five fish species belonging to 31 genera were reported from eight wetlands (Doora kere, Kuduregundihalla kere, Devibudhi kere, Yennchole kere,
Karigaladoddakere, Paduvakote kere, Santhe kere, Karimuddnahally kere) of Mysore by Prasad et al. (2009) of which genus *Puntius* was found to be represented by maximum number of species (*Puntius arulius, P. carnaticus, P. cauveriensis, P. sarana, P. filamentosus*) in all the lakes. Of all species so reported, seven species were categorized as endangered, seven as threatened and six as vulnerable as per IUCN ‘Red list of threatened animals’ (Baillie and Groombridge, 1996).

Gautam et al. (2010) investigated Jagadispur Reservoir (A Ramsar site), Nepal and reported 42 species, out of which 38 were indigenous and 4 were exotic ones. Order Cypriniformes represented the highest species composition (46%) followed by order Perciformes (21%) and order Siluriformes (19%) respectively.

Jadhav et al. (2011) investigated Sangmeshwar reservoir, Maharastra and compared ichthyofaunal diversity during different time periods viz. 2005-2010. They documented nine species earlier and nineteen species presently. Sharma et al. (2011) carried out investigations on Pichhola Lake, Rajasthan. They reported 15 species from the lake out of which maximum species belonging to order Cypriniformes were found.

Thirumala et al. (2011) analyzed fish biodiversity of Bhadra reservoir, Karnataka in relation to physico-chemical characteristics and found a total of 33 species, maximum of which belong to family Cyprinidae followed by family Channidae, family Bagridae and family Siluridae. He correlated maximum and minimum fish biodiversity with seasons viz. maximum in post monsoon which may be due to availability of sufficient water and ample food resources and vice versa minimum during pre-monsoon. Ubharhande et al. (2011) studied ichthyofaunal diversity from Ambadi Dam, Aurangabad and reported 22 genera belonging to 8 orders out of which order Cypriniformes with 13 species dominated and family Mugilidae was observed to be represented by just one species.

Bhalerao (2012) while working on Kasar Sai Dam in Pune reported 15 fishes species; both indigenous and exotic and a few small local fishes were also observed. Senthil Murugan and Prabaharan (2012) recorded a total of 35 fish species belonging to four different orders from Kamala Basin of Bihar. They further correlated high fish diversity during post monsoon due to presence of sufficient water and food resources and recorded a decline in pre-monsoon due to less available water resources.
Furthermore, they categorize the lake as oligotrophic on the basis of high value of dissolved oxygen and concentration of other nutrients.

Hamid et al. (2012) studied comaparative fish fauna of Temengor and Bersia reservoirs, Malaysia and 25 fish species belonging to 6 families were recorded from both the reservoirs. Twelve species were recored from Temengor reservoir while thirteen species from Bersia reservoir. Total catch from both the reservoirs were observed to be dominated by *Osteochilus hasseltii* and *Cyclocheilichthys apogon*. Higher total individual catch was recorded from Temengor reservoir.

Negi and Rajput (2012) assessed fish biodiversity of two lakes namely Bhimtal and Nainital lake of Kumaon Himalayas and reported 15 species from former and 9 species from later. They compared fish diversity using Shannon’s Species Diversity Index (H’) of both lakes and observed Bhimtal lake (H’ 2.359) to be having more diversity than Nainital lake (H’ 1.978) and inferred that water quality and environmental conditions of former to be more conducive for fish diversity.

Nunoo et al. (2012) analyzed Owabi Dam Reservoir in Ghana for fish composition (19 species), fish abundance (*Synodontis* sp. and *Herodontis* sp.), relative abundance (Family: Cichilidae; represented by 6 species) and species diversity (1.67). The value of species diversity index (1.67) indicated complex community structure which was further correlated to community stability i.e. resistant to external disturbance.

Pawar and Pawar (2012) recorded 50 fish species which includes 6 exotic and 42 indigenous fish species from Kanher Dam, Maharashtra and family Cyprinidae was found to be abundant (40 species) amongst all. Uchchariya et al. (2012) recorded 40 different fish species from Tighra reservoir of Madhya Pradesh and found Order Cypriniformes to be dominant with 55% contribution.

Ubharhande and Sonawane (2012) recorded freshwater fish fauna of Paintakli dam, Maharashtra. Ichthyofaunal was observed to be represented by 21 species belonging to 19 genera, 10 families and 7 orders. Family Cyprinidae dominated with 47.61% contribution followed by Channidae and Mastacembelidae with (9.52%), Balitoridae, Bagridae, Claridae, Belonidae, Notopteridae, Cichlidae, and Poecilidae contribute (4.76%) each.

Kumar Naik et al. (2013) studied ichthyofaunal diversity of Karanja reservoir, Karnataka and recorded 64 species of finfishes belonging to 37 genera, 16 families
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and 5 orders. Among all, order Cypriniformes was observed to be most dominant represented by 31 fish species followed by Siluriformes 20, Perciformes 10, Osteglossiformes 2 and order Synbranchiformes 1 fish species. Contribution of family Cyprinidae was found to be maximum (42.18%) while others contributed quite less (Bagridae 14.06%; Ambassidae 9.37%; Channidae 4.68%; Claridae 4.68%; Notopteridae 3.12%; Schilbeidae 3.12%; Siluridae 3.12%; Sisoridae 3.12%; Balitoridae 1.56%; Cichlidae 3.12%; Cobitidae (1.56%); Gobiidae 1.56%; Heteropneustidae 1.56%; Mastacembelidae 1.56% and Pangasiidae 1.56%.

2.2. Trends of fishery

Ichthyofauna of a reservoir although represents the fauna of parent river system but it usually suffers a major setback in terms of number, weight and diversity on impoundment (Negi, 2008). Jhingran (1991) opined that large reservoirs on an average support 60 species of fishes, of which 40 species contribute to commercial fisheries.

Negi (2008) conducted work on Gobindsagar reservoir and Pong dam reservoir, Himachal Pradesh so as to assess the trends of fishery during 2001-2007. He recorded a total of 11 fish species from Pong Dam reservoir, amongst which the major contributors were Aorichthys seenghala, Labeo rohita, Tor putitora, Cyprinus carpio, Cirrhus mrigala, Catla catla, Wallago attu, Channa spp., Labeo calbasu, Labeo dero, Hypophthalmichthys molitrix and Ctenopharygodon idella. All the fish species were recorded during all the years except for H. molitrix, C. idella and Labeo dero which were caught inconsistently. Maximum catch (in tons) was recorded for A. seenghala during 2001-2007 (average 250.05 tons).

Similarly 10 fish species namely, Aorichthys seenghala, Labeo rohita, Tor putitora, Cyprinus carpio communis, Cyprinus carpio specularis, Cirrhus mrigala, Catla catla, Channa spp., Labeo calbasu, Labeo dero, Hypophthalmichthys molitrix. All the fish species were present throughout all the study period and maximum catch (in tons) were recorded for H. molitrix. Decline or abrupt changes in the catch of various fish species may be because of construction of hydroelectric project on the river which leads to reduction in volume of water in the reservoir and heavy siltation.

Deka et al. (2005) analyzed 54 wetlands of Assam to compare their fish production during 1990 and 2000. In all the wetlands fish production (in kgs) declined but rate of depletion vary from one wetland to another. Minimum depletion rate was
observed to be 0.21% for Bormanaha wetland to a maximum of 75.51% for Dhaka wetland with a mean of 4.94%. The major reasons for their decline were categorized as effects of the internal environment; effects siltation; encroachment; anthropogenic activities; indiscriminate killing of brooder; overfishing and use of uncontrolled mesh size of fishing gears.

2.3. Length-Weight relationship

Length-Weight Relationship (LWR) plays a key role in fishery resource management (Ferhat et al., 2007) and is also useful for comparing life history and morphological aspects of populations inhabiting different regions (Goncalves et al., 1997). One of its most important practical applications include estimation of weight while length of the fish is known or vice versa. It helps in determining the condition factor or the Pondral index, spawning seasons and the taxonomic differences of fishes (Le Cren, 1951). The general expectation is that the weight of the fishes would vary as the cube of the length (Brodv, 1945; Lagler, 1956; Brown, 1957). The actual relationship may depart significantly (Le Cren, 1951). The exact relationship between length and weight differs among species of fish according to their inherited body shape and within a species according to the condition (robustness) of individual fish.

The study of length-weight relationship is of prime importance among other parameters, in setting up the yield equations (Ricker, 1973).

The length-weight relationship is estimated using formula:

$$W = a L^b$$

where,

- $W$ is the total weight,
- $L$ is the total length and
- $a$ and $b$ are coefficients of regression (Ricker, 1973)

Soni and Kaithal (1979) computed length-weight relationship of *Cyprinus carpio* from Tropical lake Sagar, Kaithal and ‘b’ value was observed to be 3.75, depicting positive allometric growth ($b > 3$). Johal (1994) reported variation in length-weight relationship of *Gudusia chapra* from different water bodies and found it useful in calculation of equality of correlation coefficients.

Length-weight regressions have been used frequently to estimate weight from length, as direct weight measurements can be time consuming in the field (Sinovcic et al., 2004). Johal et al. (2005) observed exponent value ‘n’ to be 3.150 for *Tor putitora* from Pong dam reservoir, Himachal Pradesh. Dua and Kumar (2006) calculated LWR
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of Channa marulius from Harike wetland, Punjab and observed negative allometric growth which is evident from the ‘b’ value (2.74).

Dulcic et al. (2009) estimated length-weight relationship for six endemic fish specimens i.e. Salmo dentex, Chondrostoma knerii, Rutilus basak, Scardinius plotizza, Squalius svalize and Cobitis narentana from Hutovo Blato wetland, Bosnia and Harzegovina and observed exponent value ‘b’ to be 3.07, 3.27, 3.31, 3.31, 3.22 and 2.80 indicating positive allometric growth except in Cobitis narentana.

Isa et al. (2010) studied length-weight relationship of fresh water fishes from Pedu lake and found value of ‘b’ to be between 2.665-4.106. They further categorized fishes into three groups on the basis of value of exponent i.e. light (b <3), heavy (b >3) and isometric (b =3) indicating poor, over and symmetric growths of length and weight respectively.

Ahmed et al. (2011) calculated length-weight relationship for six fish species in Khashm-El-Girba reservoir, Sudan and inferred negative allometric growth (b < 3) for most of the fish species (61.1%) as indicated by the value of ‘b’ (2.278-3.680). The values of correlation ‘r’ varied from 0.749-0.998.

Hamid et al. (2012) compared growth of Cyclocheilus apogon from two reservoirs (Temengor and Bersia reservoirs) of Malaysia. Positive allometric growth was observed from both the localities as evidenced from ‘b’ values (b= 3.363 and 3.414 for Temengor and Bersia reservoirs respectively). Slightly higher correlation coefficient was observed for Bersia reservoir (r²= 0.935) than Temengor reservoir (r²= 0.920).

Jayalakshimbilaja et al. (2012) calculated length-weight relationship of two freshwater fishes, Puntius chola and Puntius dorsalis from Cholavaram lake, Chennai. Isometric growth was observed with value of exponent ‘b’ to be 3.11 and 3.27 for Puntius chola and Puntius dorsalis respectively. High positive correlation (r² = 0.993 and 0.991 for Puntius chola and Puntius dorsalis respectively) was observed between length and weight.

Karna and Panda (2012) collected 20 fish species from Chilka lagoon, Orissa and calculated the value of ‘b’ which was observed to range between 2.45-3.49 for all species. Rahman et al. (2012) studied length-weight relationship of Pool barb, Puntius sophore from Chanab Beel, Bangladesh and found coefficient of ‘b’ to be 3.396
indicating positive allometric growth. A highly significant positive correlation was observed between length and weight ($r^2 > 0.945$).

Prasad et al. (2012) studied length-weight relationship and condition factor of 255 samples of *Labeo rohita* in Govindgarh Lake, Madhya Pradesh. Significantly high levels of coefficient of correlation was observed ($r^2 = 0.98**$). The values of exponent ‘$b$’ was observed to be 2.97 indicating negative allometric growth which is quite nearer to isometric growth and mean condition factor ‘$k$’ was calculated to be 1.60 which suggested good health of all the specimens.

Ujjania et al. (2012 a) computed length-weight relationship of Indian major carps (*C. catla, L. rohita* and *C. mrigala*) in Mahi Bajaj Sagar, Rajasthan and observed the value of exponent ‘$b$’ to be 3.275, 3.376 and 3.362 respectively for the pooled data. From the review, it is quite evident that fish morphometry vis-a-vis length-weight relationship hold a center stage in fish bionomics and is extremely helpful in the management and exploitation of fish population.

Zargar et al. (2012) conducted work on length-weight relationship of the crucian carp, *Carassius carassius* in relation to water quality, sex and season in 3 lakes i.e. Anchar, Dal and Manasbal lakes of Kashmir Himalayas. Results revealed positive allometric growth of *Carassius carassius* in all the three water bodies and the descending order of trend of growth on the basis of ‘$b$’ value was observed to be Anchar lake (3.13) > Manasbal lake (3.06) > Dal lake (3.02). They further studied effects of physico-chemical features and sex on L-W relationship. They inferred that prevailing environmental conditions (Tsoumani et al., 2006) and intrinsic factors (Knaepkens et al., 2002) are related to the growth of fish. Higher exponent values were observed in females as compared to males at Anchal lake and Manasbal lake but reverse results were obtained in population of Dal lake. These differences may be attributed to the feeding intensity between male and female (Shafi and Qudus, 1974; Pervin and Mortuza, 2008).

### 2.4. Morphometric characters

Fish morphology includes the study of morphometric characters (metric characters) which are measurable and meristic characters, which are countable. The use of fish morphometry dated way back to the times of Hamilton-Buchchan (1822) and Day (1875-1878). Morphometric characters can be categorized as genetically...
controlled (1-9.99 or < 10), intermediate (10-14.99 or < 15) or environmentally controlled (> 15) (Johal, 1994) on the basis of values of percentage difference/ range.

Austin (1999) stated that most of the morphometric characters are plastic i.e. environmentally controlled and are influenced by physical environment during spawning and early juvenile stages. In fish, morphometric characters represent one of the major keys for determining their systematics, growth variability, ontogenetic trajectories (Kováč et al., 1999) and/or various population parameters.

The shape and structures are unique to the species and variations in its features can be attributed to the varied environmental conditions (Cavalcanti et al., 1999). Hamza (1999) studied morphometric characters of Mugil cephalus for two successive seasons in 1988 and 1989 in Bardawil Lake, Egypt. He observed linear regression between various body measurements and total length. He calculated percentage of Y (dependent variables) to X (independent variable i.e. total length) and revealed that the percentage difference for successive years was found to be significantly different for body length in comparison to standard length and head length. In case of depth measurements, again the percentage difference for depths of pectoral and dorsal fin bases were found to be significantly different when compared to depth of caudal fin base.

Kováč et al. (1999) made studies on stone loach, Barbatula barbatula and examined it in terms of growth variability. Negi and Nautiyal (2002) observed in Barilius bendelisis that of the total morphometric characters, 54.5% characters in males and 50% in females were genetically controlled whereas in Barilius vagra 63.9% were genetically controlled characters in males and 59.1% in females, thereby indicating the Barilius bendelisis has relatively wider distribution and a greater tendency towards speciation.

Both taxonomic classification of organisms, and understanding the diversity of biological life, were historically based on descriptions of morphological forms (Dean et al., 2004). Johal et al. (2003) examined morphometric and meristic characters of Tor putitora (Ham.) and found a great degree of similarity in the environmentally controlled characters. Verep et al. (2006) examined morphometric characters of Barbus tauricus such as body depth, head length, pre-orbital distance, interorbital distance, pre-dorsal distance and postdorsal distance. Computing all parameters with standard length, Verep et al. (2006) found eye diameter to be the most variable feature.
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whereas least variability was observed for pre-dorsal distance, so they categorized eye diameter to be an environmentally controlled character and hence, eye diameter should be taken with caution in taxonomical studies.

Manimegalai et al. (2010) studied 15 morphometric characters of *E. maculatus* and observed that body weight and standard body length showed high positive correlation with total length (0.960**) in comparison to remaining other parameters.

Morphometric analysis in fishes is a very popular tool in hands of biologists for characterizing and differentiating different fish genera or between different species of a single genus. Similar work was carried out by Choudhury et al. (2011) and Choudhury and Dutta (2012) who studied interrelationships of six species of the genus *Puntius* (*P. chola, P. gelius, P. conchonius, P. sophore, P. sarana sarana* and *P. ticto ticto*) and five species of the genus *Labeo* (*L. bata, L. calbasu, L. rohita, L. pangasius* and *L. dyocheilus*) respectively. In the former studies, highest similarity index was found between *P. gelius* and *P. sarana sarana* (96.2782) and least between *P. sophore* and *P. conchonius* (74.7368) and in the latter findings, *L. rohita* and *L. calbasu* were found to be most closely related with a similarity index of 98.39 and least similarity index was observed between *L. bata* and *L. dyocheilus* (76.2756).

Ujjania et al. (2012 b) carried out biometric studies (morphometric and meristic) on *Tor putitora* from Bari Talab, Udaipur. He observed that out of 24 morphometric characters studied, 23 characters were found to be genetically controlled and 1 was environmentally controlled. He further observed positive correlation between total length and all morphometric characters with maximum correlation was observed between TL (Total Length) and SL (Standard Length) (0.966*) and minimum between TL (Total Length) and AFCB (Anal Fin to Caudal Bottom) (0.610*).

2.5. Abiotic parameters

The growing importance of wetlands has led many investigators to work on the different aspects of the wetland ecosystems, both nationally and internationally. Odum (1962) listed three major components of aquatic ecosystems – quantity and distribution of abiotic components, composition of biotic material and range of physical conditions. Physico-chemical features of a water body are of paramount importance which provides a baseline data for assessing the biodiversity and further
for planning the conservation and management strategies in case of biodiversity losses.

Any variation in the physico-chemical condition of the water is directly reflected in the biotic community of ecosystem. The abundance of the aquatic organisms in natural community is directly related to the water quality. The most significant abiotic factors which affect aquatic life include radiation, temperature, transparency, respiratory gases and biogenic salts (Odum, 1971; Agarwal, 1989). In addition, water temperature and pH are also one of the major factors which directly or indirectly influence other abiotic and biotic components as suggested by Szyper (2001).

Of late, Remote Sensing (RS) has been applied for assessing the regional water quality monitoring and assessment (Choubey, 1992; Chopra et al., 2001; Kloiber et al., 2002; Nelson et al., 2003) and these studies have demonstrated reliable relationships between water quality parameters, such as total phosphates, total nitrogen, dissolved oxygen, pH, salinity, Secchi depth, sodium and potassium, and radiance data from satellites (Dewidar and Khedr, 2001; Alparslan et al., 2007).

Salinization, water diversion, catchment’s activities, pollution (Downing et al., 1999; William, 2000) and siltation (Handa et al., 1997; Kaul, 1997; Thomas et al., 1997) are some of the major elements which affect chemical and biological characteristics of lake water. As per Wetzel (2000), sedimentation also results in decreased littoral dominance and accelerates the rate of lake ontogeny (successional development of lake ecosystem) which directly affect the chemical and biological characteristic of lake water.

Salaskar and Yeragi (2003) analyzed hydrobiological features during pre-monsoon, monsoon and post-monsoon season in Powai Lake, Mumbai. They reported an inverse relationship between pH and carbon dioxide content. Chaturbhuj et al. (2004) made ecological studies with special reference to Jamwa Ramgarh wetland, Rajasthan and recorded the range of pH of the lake between 6.8-8.5, which may be high due to buffering capacity of the system. Iqbal et al. (2004) observed that dissolved oxygen (DO) is negatively correlated with photoperiod and some other factors such as TDS, free carbon dioxide, chloride and zooplankton density also affect the concentration of DO.
Kamble et al. (2008) analyzed seasonal variation in physico-chemical parameters of Khadakwasala reservoir, Maharashtra. Their study revealed that maximum values of conductivity, magnesium, bicarbonates, chlorides, BOD were observed in monsoon season but concentration of nitrates and phosphates were observed to be maximum during post monsoon period because of the fact that precipitation eroded the nearby fields carrying fertilizers which may contribute to their higher levels immediately following monsoon.

Senthilkumar and Sivakumar (2008) investigated Veeranam Lake, Tamil Nadu for various abiotic factors and observed pH range to be between 7.9-8.4 (alkaline). They directly correlated value of pH with productivity and revealed pH as one of the major pollution indicator. Shinde and Deshmukh (2008) analyzed seasonal variations in various abiotic parameters of Zirpurwadi Lake, Maharashtra. They observed high temperature, alkalinity, hardness and more transparency in summer months but concentration of dissolved oxygen was found to be high during winter months.

Garg et al. (2010) reported seasonal variations in water quality and major threats to Ramsagar reservoir, Madhya-Pradesh and categorized it as mesotrophic water body with slightly rich amount of nutrients which may be due to agricultural runoff. He further listed large scale deforestation, heavy siltation, nutrient leaching, intensive spread of common macrophytes, over exploitation of fish resources and poaching of water birds as major threats to the aquatic ecosystem.

Manjare et al. (2010) observed physico-chemical parameters such as temperature, transparency, turbidity, TDS, pH, DO, free carbon-dioxide, total hardness, nitrates, phosphates; all well within in range. He inferred that water is non-polluted and can be employed for domestic, irrigation purposes and for pisciculture also. Gupta et al. (2011) assessed Maota, Jal Mahal and Galta lakes of Jaipur for various water parameters like water temperature, pH, alkalinity, hardness and dissolved oxygen. Highest and out of range (as per ICMR) values of pH (8.5), hardness (120 mg/L), alkalinity (460 mg/L) and lowest dissolved oxygen were observed at Jal Mahal lake. Based on the values of all parameters they categorized Jal Mahal lake to be highly polluted amongst all followed by Maota and Galta lakes.

Hulyal and Kaliwal (2011) investigated Almatti reservoir, Karnataka and observed seasonal fluctuation in various parameters. Patil et al. (2011) studied seasonal variations in abiotic factors of Lotus Lake, Maharashtra. Maximum air
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temperature, water temperature, total dissolved solids, free carbon dioxide, total hardness and chlorides were recorded in summer season whereas transparency, dissolved oxygen was maximum during winter season. Total solids were observed to be maximum during monsoon season.

Raut et al. (2011) carried out monthly analysis of three lakes of Shivaji University Campus, Kohlapur, Maharashtra viz. Bhashabhavan department lake, Music department lake and Rajaram lake from 2010-2011. High values of BOD (6.8-36.55 mg/L), COD (21.41-184.00 mg/L) and phosphates (1.00-2.78 mg/L) were observed in all the three lakes. Furthermore, Rajaram lake was found to be most contaminated in comparison to other two lakes due to various anthropogenic activities.

Sangpal et al. (2011) analyzed water parameters of Ujjani reservoir, Solapur district for two seasons viz. pre-monsoon and post-monsoon and observed the water quality to be deteriorated due to industrialization and urbanization.

Sharma et al. (2011) carried out investigations on Pichhola lake, Rajasthan and water to be moderately alkaline (7.5) and with low levels of dissolved oxygen. Dissolved oxygen showed a significant negative relation with temperature, alkalinity, total hardness, electrical conductance, nitrates, phosphates, chlorides and silicates. Shinde et al. (2011) assessed Harsool-savangi Dam, Aurangabad and inferred that water temperature is positively correlated with transparency, pH, alkalinity, chlorides, sulphates and negatively correlated to turbidity, conductivity, TDS, hardness, nitrates and phosphates.

Chandra et al. (2012) assessed water quality of Porur Lake Chennai, Hussain Sagar Hyderabad and Vihar Lake Mumbai, India. They observed that the values of pH (6.89-7.56), total hardness (41-280 mg/L), sulphates (4-8 mg/L), chlorides (49-167 mg/L), nitrates (1.1-3.6) were found to be well within the range as per Bureau of Indian Standards-10500 (1991) specification at all the three sites under investigation, but certain parameters like electrical conductivity (1041 mg/L), alkalinity (410 mg/L), calcium hardness (118 mg/L), magnesium hardness (162 mg/L), TDS (935.8 mg/L) were found be out of range and thus concluded that the water of this site is not safe for drinking.

Mondal et al. (2012) studied abiotic features of Mirik Lake, West Bengal and dissolved oxygen was found to be maximum during monsoon and winter months and lowest during summer months. Furthermore dissolved oxygen showed negative
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correlation with free carbon-dioxide. Marginally acidic pH (6.61) was observed during monsoon and highest during summer season. pH values showed positive correlation with dissolved oxygen but showed significantly negative correlation with free carbon dioxide and biological oxygen demand.

Naik et al. (2012) assessed Kunigal lake, Karnataka for a period of two years (2007-2009) and revealed higher amounts of total dissolved salts (101.08-108.50 mg/L), high turbidity 22.04-28.75 mg/L whereas poor dissolved oxygen (2.41-3.47 mg/L) was observed.

Nautiyal et al. (2012) analyzed Dodital Lake (Uttarkashi) of Garhwal Himalaya and found all water parameters below the permissible limits as suggested by WHO (1971). Temperature was observed to be positively correlated to pH, carbon dioxide, TDS, hardness, phosphate and alkalinity and conversely observed to be negatively correlated to dissolved oxygen and chlorides.

Shah and Pandit (2012) conducted physico-chemical analysis of Wular Lake-a Ramsar site in Kashmir Himalaya and found range of various parameters viz. pH from 7 to 8.8; dissolved oxygen from 3.4 mg/L to 11.5 mg/L; total alkalinity from 47mg/L to 257 mg/L; free CO\(_2\) from 8 mg/L to 28mg/L; chloride from 8.4 mg/L to 29 mg/L; ammonical nitrogen from 49 \(\mu\)g/L to 542 \(\mu\)g/L; nitrate nitrogen from 146 \(\mu\)g/L to 483 \(\mu\)g/L, orthophosphate 13.0 \(\mu\)g/L to 36 \(\mu\)g/L and total phosphate from 102 \(\mu\)g/L to 297 \(\mu\)g/L. Particularly higher values of nitrogen and phosphate indicated eutrophic nature of the lake.

2.6. Biotic parameters

Biotic parameters are constituted by the living components of an ecosystem, of these planktons are categorized either as phytoplanktons and zooplanktons depending on their nutrition status, former being autotrophic and latter heterotrophic respectively. Phytoplanktons form the basis of food chains and food webs which directly provide food for zooplankton, fishes and some aquatic animals (Millman et al., 2005; Shubert, 1984). Zooplanktons support the economically important and significant fish population as they act as a major mode of transfer of energy between phytoplanktons and fish (Howick and Wilhm, 1984).

The study of zooplankton composition, their abundance and seasonal fluctuation may thus be helpful in planning successful fishery management programs.

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Jhingran, 1991). Qadri and Yousuf (1980) opined that temperature is one of key regulators which affect occurrence, distribution and abundance of cladocerans.


Hydrobiology of Anchar lake, Kashmir was studied by Balkhi et al. (1987) and a total of 87 rotifers and crustacean zooplankters were recorded. Major contributors amongst rotifers, crustaceans and cladocerans were Asplanchna priodonta, Chydorus sphaericus and Eucyclops speratus respectively. Furthermore rotifera was observed to be the most dominant group.

Kaushal and Prakash (1996) explained spatial distribution of macrobenthos in Gobindsagar reservoir and showed the dominance of oligochaetes and mollusks in deep zones. He specially emphasized on phytoplankton as bio-indicators of water quality, which are photosynthetic and grazed upon by zooplanktons and other aquatic organisms. The primary production was recorded to be high during the month of September. High temperatures promote diatom growth (Takano and Hino, 1997), development of cyanophycean bloom (Swaranlatha and Narsinghrao, 1998), richness of phytoplankton (Simona et al., 1999).

There are various abiotic factors which at times regulate the abundance of biotic components. For instance, light, temperature, nutrient supply and grazing rates (Simona et al., 1999; Srivastava et al., 2003; Sultan et al., 2003) and light limitation by high turbidity frequently controls phytoplankton growth either during the whole year or seasonally (Ariyadej et al., 2004). Rotifers although dominated all water bodies but it showed a negative correlation with pH, dissolved oxygen and transparency whereas the Copepods showed negative correlation with water temperature, nitrates and phosphates. The cladocerans also revealed negative correlation with pH, transparency and phosphates. This indicates several abiotic factors exert a considerable influence on the zooplankton abundance (Pandey and Verma, 2004).
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Diatoms population were less abundant during summer months (Jasprica et al., 2005) but they appeared concomitantly with a dip in temperature during cooler months (Mohammed et al., 1989; Jasprica and Hafner, 2005).

Studies of Kiran et al. (2007) revealed that the density of rotifers were maximum in summer season and minimum in rainy season and vice-versa trends were observed for cladocerans, copepods and protozoans. However ostracods were found to be following an altogether different trend being maximum in winter and minimum in rainy season. Ansari et al. (2008) reported 13 species of Cyanophyceae, 12 species of Chlorophyceae and 3 species of Bacillariophyceae from Unkal lake, Hubli, Karnataka. The studies also revealed occurrence of 3 species of Protozoans, 23 species of Rotifera, 16 species of Crustaceans, 7 species of Mollusks and 10 species of Insects. Khuantrairong and Traichaiyaporn (2008) studied diversity of planktons of Doi Tao lake, Thailand and found dominance of division Chlorophyta (64 species) followed by the division Chrysophyta (42 species), division Cyanophyta (31 species), division Euglenophyta (19 species), division Cryptophyta (3 species) and division Pyrrophyta (3 species).

Hulyal and Kaliwal (2008) assessed Almatti reservoir, Karnataka with special reference to zooplanktons. They observed four major groups viz. Rotifers, Copepods, Cladocerans and Ostracods. Total 21 species belonging to 16 genera were observed of which the dominant contributor were Rotifers followed by Cladocerans, Copepods and Ostracods.

Dar et al. (2010) studied ecological distribution of macro zoobenthos in Hokera wetland, Jammu and Kashmir and observed dominance of annelids and poor representation of molluscs. He also found insects to be although represented by a single taxon i.e. Chironomus, but was abundant in all seasons. Dominance of Bacillariophyceae in a eutrophic water body can be an indicator of organic pollution as inferred by Mukherjee et al. (2010).

Datta (2011) analyzed zooplankton diversity in relation to physico-chemical parameters of two wetlands of Jalpaiguri, West Bengal and inferred rotifers to be the richest group where as Brachionus enjoyed numerical superiority over Lecane. Zooplankton diversity was found to be significantly positively correlated with total suspended solids, submerged macrophytes and negatively correlated with BOD and free CO$_2$ of water.
Sharma (2011) observed rotifera as a dominant group while Cladocera and Copepoda as sub-dominant groups in two floodplain lakes of Manipur. Sharma and Sharma (2011) reported a total of 189 species of zooplankton from Loktak Lake, Manipur (a Ramsar site, India). It is the overall highest known zooplankton richness till date from any individual aquatic ecosystem and hence reflects greater heterogeneity of this Ramsar site. Zooplankton richness showed negative correlation with hardness, chloride and Rotifera dominated the site followed by Cladocera and Rhizopoda.

Seasonal periodicity of plankton and benthic fauna community structure and diversity in Aswan reservoir, Africa was studied by Iskaros and El-Otify (2012). A total of 130 taxa were observed among which 75 were phytoplanktons, 33 zooplanktons and 22 were benthic organisms. Chlorophyceae was observed to be the most dominant group followed by Bacillariophyceae, Cyanophyceae and Dinophyceae. Similarly among zooplanktons rotifers with 23 species dominated the reservoir with a just 7 and 3 species of cladocerans and copepods respectively. Benthic fauna was found to be represented by mollusca, larvae of chironomids, oligochaetes, platyhelminthes, hirudinea and decapods.

Shukla et al. (2012) studied biotic spectrum of Chando lake, Uttar Pradesh in context of ecological status and zooplankton diversity and recorded 23 species of zooplankton. Rotifers were the most abundant group followed by copepods and cladocerans. Protozoans were found to be least abundant. Seasonal analysis revealed maximum protozoans during post monsoon, cladocerans, copepods and rotifers during pre monsoon season. Overall zooplankton population was observed to be passively correlated to various physico-chemical factors like total hardness, total alkalinity, pH and chloride. Summarwar (2012) studied plankton diversity of Bilaspur reservoir, Chhattisgarh and four major planktonic algal groups viz. Chlorophyceae, Euglenophyceae, Bacillariophyceae and Cyanophyceae were observed. Zooplankton population was observed to be represented by Protozoa, Rotifera, Cladocera and Copepods.

Tyor and Chawla (2012) surveyed Sukhna lake, Chandigarh for assessment of phytoplankton ecology and reported 89 algal taxa. Furthermore, the assemblage was dominated by members of Chlorophyceae (37 taxa) followed by Cyanophyceae (26 taxa), Bacillariophyceae (19 taxa), Dinophyceae (2 taxa), Euglenophyceae (2 taxa)
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and Cryptophyceae (1 taxon). *Closterium* spp. and *Spirogyra* spp. dominated over other chlorophyceae members. *Cyclotella* sp. and *Cymbella* spp. predominantly represented Bacillariophyceae whereas *Nodularia* spp. was found to be predominant group of cyanophyceae.

Shivashankar and Venkataraman (2013) analyzed zooplankton diversity and their seasonal variations of Bhadra Reservoir, Karnataka, India and observed a total of 23 species among which rotifers were observed to be represented by 8 species followed by cladocera and protozoans both represented by 5 species, 3 species of both copepods and cladocerans and 2 species of ostracods. Copepods with 25.13% of the total zooplanktons so reported dominated the reservoir followed by rotifers, cladocerans, ostracods and protozoans. Furthermore, seasonal abundance was found to be maximum during summer season due to different environmental and inflow characteristics of the water body.

Sehgal *et al.* (2013) recorded seven species of zooplanktons viz. Rotifera (1), Cladocera (1), Copepoda (4) and Ostracoda (1) from Dimbhe reservoir, Maharashtra. Copepoda was observed to be most commonly occurring and *Cypris* was the most dominant one. Zooplankton density followed the order Copepoda > Ostracoda > Rotifera > Cladocera during winter as well as summer season.

2.7. Threats to wetlands

Wetlands are highly fragile but vital and productive ecosystems of the world because of their role in conservation of fish biodiversity. Some of them are designated as Ramsar site on the basis of number of threatened fish fauna they support (Kottelat and Whitten, 1996). Siltation from the adjoining hills, blooming industries, thermal power plant, inflow of chemicals from nearby urban areas and invasion by weeds like *Parthenium* and *Lantana* were found to be some of the major threats reported in Ropar wetland, a Ramsar Convention site in Punjab (PSCST 1992 a; Ladhar and Handa 1992; Ladhar, 1995).

Some general problems related to Kanjli wetland were observed to be excessive weed growth (mainly, water hyacinth), reduced inflow of water, increased pollution levels, deforestation in catchment areas, excessive grazing and soil erosion as documented by PSCST 1992 b; 1998; 2000. A constant decline has been observed in fresh water fish fauna due to various factors, reasons of which can be categorized either as natural causes or anthropogenic impacts (Dudgeon *et al.*, 2006).
Amongst the natural causes, drainage and surface runoff are the major factors which lead to heavy wetland losses in agricultural areas. Eutrophication is another big dilemma for wetlands downstream from agricultural and urban lands. Weed choking (specially *Eichhornia* and *Hydrilla*) and their quick multiplication in certain wetland at times cover whole water bodies making it very obscure for aquatic organisms to breathe even as for instance, Harike wetland though represented one of the largest Ramsar site in northern India with 41 km² earlier now reduced to 28 km² out of which 8-10 km² represent fresh water ecosystem and rest is weed infested (PPCB, Punjab Pollution Control Board, 1995).

In Punjab, Ladhar (1995) reported that the main causes of wetland loss have been drainage, reduced inflows, siltation and encroachment in addition to hydrobiological alterations, salinization, sedimentation and exotic species invasion (Zedler and Kercher, 2004). Dudgeon (2003) was of the view that effects of habitat loss are very poorly documented in Asia. According to the US Environmental Protection Agency (USEPA, 1986), "invasive species are thought to have been involved in 70% of this century's extinctions of native aquatic species." (US Environmental Protection Agency website on Invasive Non-Native Species).

According to one estimate, it has been found that anthropogenic activities accounted for roughly 50% global wetland losses. Ever increasing population, pollution (point and non-point sources), rapid industrialization, discharge of sewage from approved and non approved sources (Ansari *et al.*, 2008), dam construction and over exploitation of resources are the major man made impacts. It seems likely that all wetlands are degraded and the various variables responsible for this are the magnitude and the type of degradation.

Over the last few years, the fresh water fish diversity has been on regular decline. The role of wetlands in conserving fish diversity has been acknowledged as these ecosystems are used by fishes as refuge for breeding, feeding and nesting purposes at one or the other stage of their life cycle (Wetzel *et al.*, 2001). Katano *et al.* (2006) found dams and barrages impede movement of fishes so their diversity decreases downstream of the barrage.

Negi (2008) reported qualitative as well as quantitative decline in fish population at Gobindsagar reservoir and Pongdam reservoir due to construction of hydroelectric projects on river Sutlej and Beas respectively, which in turn led to heavy
and rapid sedimentation, destruction of spawning ground of fishes, blockage of their migration channels and leaching of nutrients from soil.

Unfortunately, the role of wetlands in fish conservation is poorly documented in the Punjab state (Johal and Tandon, 1979, 1980). Thereafter only isolated references are available on freshwater fish biodiversity in wetlands of Punjab (PSCST, 1992a, b; 1998; 2000; Verma et al., 1994; Ladhar, 1995; 2001; 2002; 2003; Dhillon and Kaur, 1996; Brarich and Ladhar, 2005). Therefore the present investigation is an attempt to prepare a comprehensive study of all the biotic and abiotic parameters of the Nangal wetland.