5. Discussion

Reservoirs are the most precious man made aquatic resources for the living components and its utility depend on biotic and abiotic factors. The assessment of these parameters provides the spectrum of information which are helpful for the conservation of aquatic resources, aquatic fauna and flora, better fisheries management and sustainable utilization. The states and union territories contribute fish production but over two-third of this output is mainly obtained from five states like West Bengal, Kerala, Gujarat, Maharashtra, and Tamil Nadu.

Gujarat is the second largest fish producer in the country, it shows tremendous development in inland fisheries over the last three decades and growth is admirable which resulted that fish production of the state was 747.33 tonnes in 2006 which has been increased to 793.42 tonnes in 201415 in that 22.07 percent and 1.41 percent contributed by marine and inland fisheries sector respectively (Goswami and Zade, 2015).

The health of aquatic resources depends on the physical, chemical and biological characteristics (Venkatesharaju *et al.* 2010). Study of water quality of any aquatic resource provide significant informations which support the fish life and play significant role in the biology and physiology of fish (Dhawan and Kaur, 2002).

Temperature

The most common physical assessment of water quality is temperature because it affects the chemical, biological and physical property of water. Water level, wind and water velocity, solar radiation, humidity etc. affect the water temperature of reservoir (Johnson, 2004). Fish are very sensitive, and its metabolism rate is directly influenced by water temperature. The mean temperature (29 ºC and 30 ºC) of Vallabhsagar reservoir was observed which was within the range of parameter prescribed by Bhatnagar and Devi (2013). Bera *et al.* (2015) mentioned that temperature range 27-31 ºC was suitable for fishery distribution in Kangasbati reservoir similarly Pandit and Nakamura (2010) concluded that water temperature between 27-32 °C was most effective for rearing of Nile tilapia whereas >32 °C resulted in slow growth, reduced feeding and increased mortality. Kausar and Salim (2006) concluded that temperature between 24-26 °C was the most effective for rearing of *Labeo rohita*. Sachidanandamurthy and Yajurvedi (2005) were reported that temperature 28 to 32 ºC of Bilikere lake, Mysore which was conducive for fish culture.

High temperature during summer attributed to low water level, low velocity, clear atmosphere and high solar radiation while it was low in winter due to low solar radiation, frequent clouds, high percentage of humidity, high current velocity, reservoirs location and high-water levels.

Similarly, maximum temperature in summer and minimum temperature during winter have been reported by Mohammad *et al.* (2015) from Wyra Reservoir, Telangana due to its location and climatic condition. Shinde and Singh (2014) reported seasonal temperature difference due to location and size of Mod Sagar Jhabua (M.P.). Bhadja and Vaghela (2013) reported the maximum temperature during summer while minimum temperature during winter season in Aji reservoir, Saurashtra (Gujarat). Sharma *et al.* (2000) observed that water temperature fluctuates between 21 °C to 29 °C in Udaipur lakes during different season.

Turbidity

Water turbidity is attributed to the suspended substances like clay, silt, sand particles and planktons. High turbidity in studied area was in month of August that may be due to influx of rain water from catchments area and suspended inert particulates matter. However, minimum turbidity in May comprises due to low water level and less current disturbance.

According to Zweigh (1989) turbidity in the range of 20-30 NTU is suitable for fish culture and present investigation is in consonance with the reported study. Shinde and Singh (2014) from Mod Sagar, Ehiagbonare and Ogunrinde (2010) from Okada water body, Nigeria and Sharma *et al.* (2000) from Udaipur Lake reported the turbidity range 5-20 NTU which was suitable for fish survival.

The turbidity of Vallabhsagar reservoir was high during monsoon or breeding season while it was recorded low during pre-breeding season due to low water level, less water current and settling of sediments. Similar observations were also reported by Srivastava *et al.* (2011), in this report it was describe that high and low turbidity was observed during breeding and post and pre-breeding season in Mahi river, Gujarat. Garg *et al.* (2006) from Harsi reservoir and Dagaonkar and Saksena (1992) from Kaila Sagar reported high turbidity in rainy season and less during winter and summer due to fluctuation in intakes like silt, clay and other suspended particles.

Total solid

The total solid is the measurement of dissolved and suspended matters like dissolved salts, soil particles, discharged effluents and decomposed organic matter in water. It found highly fluctuated parameter in Vallabhsagar reservoir while average findings of it was below the maximum permissible limit for fish culture given by Bhatnagar and Devi, (2013). Parikh and Mankodi (2012) reported the range of total solids (1000-2000 mg/L) which was more than the normal range for aquaculture in Sama pond, Vadodara due to high organic load. However similar observation of total solid was recorded by Khan *et al.* (2012) in Triveni lake in Maharastra, Saxena and Saksena (2009) in a culture pond (Gwalior) and Paulose & Maheshwari (2006) in Ramgarh lake (Rajasthan).

In present study, total solids were high during breeding season while its value was low during winter and summer due to interferences of flood and precipitation. Total solids showed a considerable increase during the rainy season followed by drastic decline during winter season in Bhadra river, Karnataka (Shivashankar and Venkataramana, 2015). Taheruzzaman and Kushari (1995) found the range of total solid 50 to 2240 mg/L in Ganga waters and reported that it was lower during winter and summer due to less water current and turbulence.

Total dissolve solids

Water is universal solvent and number of salts, minerals are dissolved and influence the physicochemical properties (Choudhary *et al.* 2014). The amount of total dissolve solids in the water of Vallabhsagar were fluctuated due to rain, sedimentation, rock erosion, water current, wind velocity, temperature, turbidity and water level etc. The average value of total dissolve solids during the study duration was not exceed than the maximum permissible limit 300-500 mg/L for fish culture (Sharma, 2008). Shinde and Singh (2014) noted TDS <200 mg/L in Mod Sagar and concluded that waterbody possess healthy condition for spawning of fishes. Dwivedi and Sonar (2004) reported TDS 150 mg/L in a small reservoir in Arunachal Pradesh similarly Tiwari (1999) observed TDS 150 to 192 mg/L (mean value 170 mg/L) in Upper Lake water, Bhopal which was quite similar to the result of present study and suitable for fish survival.

Total dissolved solids show cyclic pattern of seasonal changes and it was maximum during rainy season and minimum in winter. This indicated that the dissolved materials were of allochthonous origin, which was brought in reservoir by surface runoff. Mohammad *et al.* (2015) studied the effect of seasonal variation in total dissolve solids of Wyra reservoir, Telangana and reported that it was high during July to September and then decreases simultaneously afterwards. Medudhul *et al.* (2012) reported the high TDS value during rainy season due to water runoff from catchment area in Manair reservoir, Karimnagar district of Andhra Pradesh. Sakhare and Joshi (2003) found the high value of TDS during post monsoon as large amount of sediment load was transported from the watershed during the rainy season and low during pre-monsoon due to absence of allochthonous material in minor wetland (Maharashtra).

Total suspended solid

The total suspended solids in water is due to the substances that are found in suspension forms like silt, clay and plankton. CIFE (1997) reported the range of 30-200 mg/L of total suspended solids is suitable for aquaculture. Total suspended solids in Vallabhsagar reservoir was noted high during

August and September due to heavy inflow of water from catchment area while it was low during April and May month due to less inflow of water. However mean value of TSS was within the range prescribed by CIFE (1997). Saxena and Saxena (2013) reported the total suspended solid in Raipur reservoir between 84.3 mg/L and 114.0 mg/L the reservoir followed a seasonal trend with low dissolved solids in December. Saxena (2012) and Agarwal & Rajwar (2010) reported the conduciveness of Raipur reservoir and Tehri dam for aquaculture as the value of TSS during different season not exceeded the maximum permissible limit (< 500mg/L) prescribed by CIFE (1997).

High values of total suspended solids in Vallabhsagar reservoir were observed during breeding season due to increased surface runoff from catchment area which exceed the level of silt, clay and other organic and inorganic maters and low during pre-breeding season due to low water level, less water turbulence and less plankton growth. High total suspended solid in Mangrul dam was reported due to influx of water from catchment area during breeding season (Jawale and Patil, 2009). Salve and Hiware (2006) reported low suspended solid in winter season while maximum in monsoon due to addition of solids from surface run off in Wanparakalpa reservoir, Nagapur (Maharashtra).

Dissolve oxygen

The dissolved Oxygen is remarkable parameter to determine the water quality of an aquatic system because it regulates metabolic activities of aquatic fauna. It governs metabolism of the biological community and used as an indicator of trophic status of the water (Saksena and Kaushik, 1994). In Vallabhsagar reservoir, high value of dissolved oxygen was recorded in December month that may be due to low water temperature and low during the month of May as the increase of temperature. Although it shows monthly variation during study period, but it remains well above the minimum level (>5ppm) to support good fish production (Banerjea, 1967). Similar trends of it also reported by Gonjari and Patil (2008) in Triputi reservoir near Satara, Singh *et al.* (2010) in Mansagar Lake of Jaipur and Esmaeili & Johal (2005) in Gobindsagar,

Level of dissolved oxygen in Vallabhsagar was quite satisfactory during monsoon and the winter perhaps due to good aeration caused by rain water whereas it was low during pre-monsoon season due to rise in temperature and low water level. Similar observation was reported by Karthick *et al.* (2016) from Kadamba tank, Tamil Nadu. Bera *et al.* (2014) reported the high oxygen during rainy season due to aeration while low value in the dry season due to increased water temperature in Kangsabati Reservoir, West Bengal. Rani *et al.* (2004) also reported low value of dissolved oxygen in summer season due to higher rate of decomposition of organic matter, limited flow of water and elevated temperature.

Hardness

Total hardness indicates the presence of total quantity of divalent salts in the water. Comparatively soft water, Hard water causes osmoregulatory stress in fishes CIFE (2013) and Stickney, (2013). The average value of hardness (<150 mg/L) was found in Vallabhsagar reservoir and it was suitable for fish farming. Kasiri *et al.* (2011) stated that soft water (10 mg/L $CaCO_3$) and hard water (300 mg/L $CaCO_3$) was not suitable for *Pterophyllum scalare* incubation and larval rearing. Hardness range 20150 mg/L is suitable for the growth of fish (Balaji, 2015) and the finding of current study was quite similar to this. The similar range of hardness was also reported by Lianthuamluaia *et al.* (2013) from Savitri reservoir Raigad (Maharashtra) and Ibrahim *et al.* (2009) from Kontagora reservoir, Nigeria.

Seasonal variation in water hardness is necessary for aquatic productivity because it protect the fishes from harmful effects of pH functions (Kodarkar, 1992). In Vallabhsagar it was recorded high during post breeding season due to the high concentration of carbonates and bicarbonate salts of calcium and magnesium and low during breeding season due to dilution of these ion as the water level was high. Similar observation reported by Singh *et al.* (2010) from Mansagar lake Jaipur, Sinha and Biswas (2011) from Kalyani lake West Bengal and Khan *et al.* (2012) from Triveni lake Amravati district, Korai *et al.* (2008) from Keenjhar lake (Sindh), Salve and Hiware (2006) from Wanparakalpa reservoir (Maharashtra), Muley and Patil, (2006) in Pauna river (Maharashtra) and Rath *et al.* (2000) in Nandira Brahamni river (Orissa).

Nitrate-N

The nitrate content in Vallabhsagar reservoir was observed within the standard permissible limits for Aquaculture prescribed by Bhatnagar and Devi (2013). The presence of nitrate in waterbody depends on the activity of nitrifying bacteria, domestic and agricultural components. The findings of Apollos *et al.* (2016) from Zobe reservoir (Nigeria), Prabhakar *et al.* (2012) in Krishnagiri dam Tamil Nadu, India, Sinha and Biswas (2011) in Kalyani reservoir of West Bengal, Garg *et al.* (2006) in Ramsagar reservoir (Datia), Dagaonkar and Saksena (1992) in temple tank Kailasagar (Gwalior) were similar to the present study.

Nitrate levels in Vallabhsagar reservoir water often shows seasonal fluctuations and it was high during monsoon months compared to summer and winter months could be due to algal assimilation and other biochemical mechanism whereas higher during monsoon may be due to surface run off with nitrogenous fertilizers. Shinde and Singh (2014) reported the high nitrate level in Mod Sagar, Jhabua, (M.P.) Saxena and Saksena (2013) in Raipur reservoir (M.P.) and Murthuzasab *et al.* (2010) in Hirahalla reservoir, Karnataka during monsoon season due to erosion and transportation of nitrogenous rich fertilizers, soil from catchment area.

Nitrite-N

Nitrite is intermediate form of de-nitrification and nitrification reactions in nitrogen cycle. It is very unstable form and converted in ammonia or nitrate depending upon the conditions of the water. Nitrite level in

Vallabhsagar reservoir was within the desirable limit given Bhatnagar and Devi (2013). Saxena (2012) reported the high concentration of nitritenitrogen (0.033 mg/L to 0.089 mg/L with an average of 0.058±0.003 mg/L) in Raipur reservoir due to low temperature and less decomposition process. Sachidanandamurthy and Yajurvedi (2006) reported the monthly variation in nitrite concentration from different water bodies of India.

Stone and Thomford (2004) suggested that 0 to 1 mg/L nitrite is desirable for warm water fishes whereas Iwama *et al.* (2000) reported that the average nitrite level 0.015mg/L is optimum for rearing of salmonids.

In Vallabhsagar reservoir high nitrite level recorded during the summer and monsoon season due to evaporation of water in summer and influx of nutrients from catchment area. The pattern of nitrite-nitrogen concentration in this reservoir was quite similar to the findings of Prabhakar *et al.* (2012) from Krishnagiri dam (Tamil Nadu), Sulthana *et al.* (2011) from Arasankulam pond Tamil Nadu, India, Garg *et al.* (2009 and 2010) from Ramsar reservoir Datia, and Thilaga *et al.* (2005) from Ooty lake, Tamil Nadu.

Total kjeldahl nitrogen

Total kjeldhal nitrogen (TKN) is the sum of free-ammonia and organic nitrogen which play vital role in growth of primary producers in water. The main sources of TKN in aquatic ecosystem are nitrogenous substances containing decay plant and animal components. In present study, Total Kjeldahl nitrogen was within the prescribe limit given by APHA, (2005). Rajamanickam and Nagan (2016) reported the high Kjeldhal nitrogen from Major lakes from Tamil Nadu due to organic pollution and agricultural runoff. Agrawal and Rajwar (2010) reported the Total Kjeldahl nitrogen 0.27 to 4.48 mg/L in Tehri dam and concluded it as pollution free reservoir. In Vallabhsagar reservoir total kjeldahl nitrogen was high during summer season as subjected to water evaporation and low during monsoon season due to high influx of nitrogen containing component in water. Similar trend in seasonal fluctuation of Total Kjeldahl nitrogen was reported by Chittora *et al.* (2017) from Major lakes of Udaipur, Chandani *et al.* (2017)

from reservoirs of central Gujarat and Mandal *et al.* (2010) from Yamuna river, Delhi.

Organic Nitrogen

In water, organic-N is biologically transformed from ammonium and then to the nitrite and nitrate form which can be used by algae and aquatic organisms and convert back to organic forms of nitrogen (Heiskary *et al.* 2010). Level of organic nitrogen in water influenced by other water parameter and digestion process of microorganism (Berman, 1997). Organic nitrogen in Vallabhsagar is observed very less whereas its high concentration in waterbody is subjected to pollution reported by Czerwionka (2016) from Baltic sea.

The estimated organic nitrogen deposited into Baltic Sea from Poland through discharge of biologically treated wastewater was recorded high

0.5 g to 1.3 g/l per day (Czerwionka, 2016). Similarly, Herrera, *et al.* (2013) reported high organic nitrogen in alluvial aquifer and dependent river water due to agricultural soils.

Ammonia

Nitrogen is used to build proteins which is essential for plant and animal growth whereas it reported toxic to aquatic organisms if it is beyond 0.1 mg/L (Bhatnagar and Devi, 2013).

The most important source of ammonia in water bodies is the ammonification of organic matter and its higher concentrations becomes harmful to fishes (Trivedy and Goel 1986). Ammonia concentration of Vallabhsagar reservoir observed < 0.1mg/L that may be due to less organic load. Karthick *et al.* (2016) from Kadamba fish tank, Tamil Nadu and Sachidanandamurthy & Yajurved (2006) from aquaculture body of Karnataka reported the ammonia concentration 0.001 mg/L and <0.2 mg/L respectively. Similarly, Sakesana (2012) and Krishnamoorthi *et al.* (2011) reported the ammonia concentration between 0.4 to 1.5 mg/L from Raipur (M.P.) and Veeranam (T.N) reservoir respectively.

Seasonal ammonia concentration in Vallabhsagar reservoir was low during breeding due to influx of fresh water from catchment area and high during post breeding season due to high organic matter oxidation, similar findings were documented by Karthick *et al.* (2016) from Kadamba tank Tamil Nadu, Pulugandi, (2014) in Vembakottai water reservoir, Virudhunagar (Tamil Nadu) and Yerli *et al.* (2012) from lake Mogan, Turkey.

Phosphate

Phosphate is essential nutrient that stimulate the growth of phytoplankton and aquatic plants which are food contents for fish. If it exceeds than the maximum permissible limit will lead to the algal bloom, choke up the waterway and use the large amount of oxygen (Murthuzasab *et al.* 2012).

The annual mean of phosphate (3.5 mg/L) was noted in Vallabhsagar reservoir which was not exceed the permissible limit prescribed by Bhatnagar and Devi (2013), Bhatnagar *et al.* (2004), Stone and Thomforde (2004). Seher (2015) studied the water quality of Camligoze lake, Turkey and reported the phosphate level (0.05-0.3 mg/L) which help to maintain healthy aquatic ecosystems for fish life. Shinde and Singh (2014) reported the phosphate (0.25 to 1.26 mg/L) and productivity of Mod Sagar, Jhabua, M.P. Phosphate and its suitability for fish health from Krishnagiri dam was reported by Prabhakar *et al.* (2012). Similar findings were also reported by Ganesan and Sultan (2009) from Chrompt lake (Chennai) and Kaushik & Saksena (1999) from different water bodies of central India.

In Vallabhsagar reservoir, phosphate was noted high during breeding and low during pre-breeding season which may be due to inflow of phosphate content from catchment runoff. The low content of phosphate in summer season may be due to more utilization of phosphate by the phytoplankton. Similar results were documented by Prabhakar *et al.* (2012) from Krishnagiri dam, Murthuzasab *et al.* (2012) from Hirahalla reservoir (Karnataka), Ganesan and Sultan (2009) from Chrompet lake (Chennai), Kaushik and Saksena (1999) from important water body of central India and Panday *et al.* (1992) from Mahananda river, Katihar (Bihar).

Silica

The amount of silica in water is influenced by various factors like saturation deficit of aeration, precipitation, temperature, bedrock reactivity and mineral stability (Dariusz 2005). The silica level of Vallabhsagar reservoir was observed 20 mg/L that may be due to geochemical characteristic, low erosion and weathering activity. The findings of Boukari *et al.* (2016) from Kpassa reservoir (Northern Benin) and Sakesana (2012) from Raipur reservoir is quite similar to present investigation.

In rainy season silicate level in Vallabhsagar reservoir was increased due to runoff from surrounding catchments area. Occurrence of low silica in winter was to be related to their continuous utilization by plankton specially diatoms, lesser decomposition activity due to low water temperature and sedimentation. Such phenomenon of seasonal variation also reported by Saxena (2012) from Raipur reservoir, Sulthana *et al.* (2011) from Arasankulam pond in Tamil Nadu, Garg *et al.* (2006 and 2009) from Ramsar reservoir and Kaushik & Saksena (1991) from Suraj kund, Gwalior.

Chlorophyll-a

The chlorophyll-a is an important parameter to evaluate the water quality with reference to nutrition status and provide the useful information to manage water quality for fishery purpose (Clarke *et al.* 2006). Chlorophyll-a concentration in Vallabhsagar reservoir was within the limit which is appropriate for fish and aquaculture. Similar chlorophyll-a range (0 to 0.56 mg/m^3) was reported by Kalman *et al.* (2003) from Balaton lake (Hungary). Soni and Ujjania (2015) studied the chlorophyll-a from Vallabhsagar reservoir which is quite similar to present findings. Similar concentration of chlorophyll-a was also reported by Kunlaska *et al.* (2013) from northern Thailand and Minte-vera (1997) from Campinas reservoir, Brazil.

Seasonal fluctuation in chlorophyll-a concentration was visible and it was more during pre-breeding season and less during breeding season may be due to temperature variations and amount of available nutrients. Similar observation was recorded by Balali *et al.* (2013) from Alma Gol Wetland, Iran. Yerli *et al.* (2012) observed the chlorophyll-a range from 2.28 to 17.86 mg/m^3 in Lake Mogan, Turkey due to seasonal temperature variation and availability of nutrients.

Plankton

In aquatic environment, most of the organisms subsist on live food consisting of plants and animals obtained from the water which is known as plankton (Bera *et al.* 2014) and estimation of plankton density in waterbody is very important for fisheries management. The topography and the surrounding environmental conditions of Vallabhsagar reservoir is favourable and resulted abundant plankton communities (1000-3500 no/L) during the study which is within the desirable range of plankton density is 3000–4500 individual/L for fish culture (Bhatnagar and Devi, 2013). Soni and Ujjania (2015) reported plankton production 2115.88±315.55 no/L in Vallabhsagar reservoir which is favourable for fish production. Dube *et al.* (2014) reported mean plankton density 2133 no/L of Kaliasote reservoir, Bhopal due to rich nutrient status.

Comparisons of seasonal plankton density showed quite random fluctuations in studied area and it was more during pre-breeding season due to ambient temperature and limited water flow while it was less during breeding season due to flooded situation. Alhassan (2015) reported the high plankton abundance in Bui dam, Ghana during pre-breeding and post breeding season due to favourable physical and chemical condition of reservoir. Seasonal variations in phytoplankton abundance with higher density during pre-breeding season also been reported by Bera *et al.* (2014) from Kangsabati Reservoir (West Bengal), Emmanuel and Onyema (2007) from tropical creek (western Nigeria) and Erondu & Chinda (1991) from Calabar river (Nigeria).

The living components shows growth in the form of length and weight and relationship in these variables or parameters having applied and basic importance. The length-weight relationship is one of the standard methods that yielding authentic biological information with two objectives, firstly it establishes the mathematical relationship between the two variables (length and weight) to know the variations from the expected weight for the known length groups and secondly this reflects its fitness, general wellbeing, gonad development and suitability of environment of the fish (Le Cren. 1951). Barrich and Kaur (2015) studied the length-weight relationship of *Catla catla* from from Harike wetland (Ramsar Site), Punjab. Gokhale *et al.* (2015) estimated the length-weight relationship of hybrid rohu catla from Lake Udaisagar, Udaipur, Rajasthan and Behera *et al.* (2015) described the length-weight relationship of *Cirrhinus mrigala* Panchasayar, water body of West Bengal. Patel *et al.* (2014) described the length-weight relationship of *Cyprinus Carpio* in Govindgarh Lake, Rewa (M.P.). The study on length-weight relationship and age and growth of Indian major carps form Vallabhsagar reservoir, Gujarat is the first attempt that could be serve as tool to provide insight into growth strategies of these species and provide the important information on fish biology in this particular water body which may be helpful for the management of waterbody and preparation of policies for fisheries management.

The present study follows the efficient sampling protocol including the wide data range of length and weight which were obtained from large samples. Variations in fish size of catla, rohu and mrigal indicated that the fish population ranged from immature specimens to fully matured ones.

During research duration, 1584 specimens of catla, 1492 specimens of rohu and 1408 specimens of mrigal were analysed for length frequency distribution and observations depict that maximum contribution of length group 50-60 cm of catla and rohu while it was 40-50 cm for mrigal due to better survival and adaptability of various food materials. Similar results of length frequency observations were reported by Gokhale *et al.* (2015) for rohu catla hybrid in Udaysaga Lake. Ujjania *et al.* (2012) mentioned that maximum frequency of catla was at the length of 55 to 65 cm in Mahi Bajaj Sagar, Rajasthan.

The length-weight relationship of catla, rohu and mrigal in Vallabhsagar reservoir shows the three-dimensional growth at different length groups of the fishes. The correlation coefficient ‘r’ of catla and rohu is 0.557, 0.667 for small fishes (40-50 and 50-60 cm) but high 0.917 and 0.963 for large fishes (90-100 cm) respectively. In case of mrigal it was significant 0.596 and 0.554 for small (40-50 cm) and 0.901 and 0.913 for big fishes (60-70 cm). However, correlation coefficient for pooled data was highly significant for catla (0.981 and 0.971), rohu (0.942 and 0.961) and mrigal (0.969 and 0.941) during the study period. The observation on the length–weight relationship shows that linear relationship holds only when the fish forms and its specific gravity remain constant throughout the active growth period.

The differences in the correlation coefficient (r) could be due to the more linear growth before sexual maturity and more weight increase after sexual maturity. Ujjania and Soni (2017) reported the correlation coefficient of catla varied between (0.557 to 0.933) for different length groups and 0.975 for pooled data from Vallabhsagar reservoir. Mir *et al.* (2014) reported the correlation coefficient of *Labeo rohita* from six drainages of Ganga river between 0.97 to 0.98 whereas Ujjania *et al.* (2013) reported the correlation coefficients of rohu varied between 0.74 to 0.88 for different length groups and 0.99 for the pooled data in Mahi Bajaj Sagar, Rajasthan. Similar values of correlation coefficient were also reported by Saxena and Saksena (2013) for catla in Raipur reservoir and Sarang and Sharma (2010) for *Labeo calbasu* from Jawahar Sagar Dam, Rajsthan.

The correlation coefficient “r” was 0.981, 0.942 and 0.969 in length and weight analysis of catla, rohu and mrigal which shows positive relationship between these variables during the breeding, post breeding and prebreeding season. It depicts that increment in length and weight of fish are directly proportionate during all season. Similar results on LWR were reported by Keyombe *et al.* (2017) in nil tilapia from Lake Naivasha (Kenya) specifying coefficient values 0.95 for breeding and 0.86 for prebreeding season. Seiyaboh *et al.* (2016) noted the correlation coefficient 0.37 and 0.61 during pre-breeding season and 0.93 and 0.41

during breeding season for *Hepssetus odoe* and *Polypterus senengalus* respectively from Niger delta. High correlation coefficient values 0.95 and 0.94 for female and male tilapia from Lake Zavi (Ethiopia) reported during breeding season (Negassa and Getahun, 2003).

Growth of fish described as either allometric or isometric depends on regression coefficient or exponent value (b) of the length-weight relationship and it lies between 2.0 to 4.0 (Hile, 1936; Martin, 1949 and Pervin & Mortuza, 2008). The value of b is 3.0, it shows that growth of fish is isometric and if its value either more or less than 3 depicts allometric growth of fish (Mohanty *et al.* 2009). In the present study regression coefficient (b) was analysed for different length groups and observed (3.12-4.36) for catla, (2.72-3.47) for rohu and (2.69-3.62) for mrigal during 2013-14 and 2014-15 signifying the allometric growth whereas pooled data analysis shows (2.94, 2.69) for catla, (3.18, 2.75) for rohu and (3.00, 2.83) for mrigal during 2013-14 and 2014-15 also postulating allometric growth that may be attributed to numbers of factors such as sex, temperature, salinity, food, habitat, pollution level, maturity, season and physiological differences in fishes. Balai *et al.* (2017) reported negative allometric growth (2.60) for catla, positive allometric growth for rohu (3.10) and isometric growth for (3.00) for mrigal in Jaisamand lake Rajasthan. Negi and Negi (2009) reported regression coefficient 3.0

resulted isometric growth in puntious from lake Kimaonand, Uttarakhand while Negi (2013) reported the isometric growth in rohu from fish pond of Roorkee, India. Ujjania *et al.* (2013) reported regression coefficient between 2.97 to 3.13 for rohu from different water bodies of southern Rajasthan. Sachidanandmurthy *et al.* (2013) reported ‘b’ value between 1.5-2.17 for catla from Mysure Lake, Karnataka shows negative allometric growth. Bhat (2011) reported the isometric growth for *Labeo rohita* from Phuj reservoir, Jhansi whereas Sarkar *et al.* (1999) reported the positive allometric growth (b=3.30) in rohu from fish hatchery of Calcutta.

In the present study catla, rohu and mrigal exhibit isometric growth during breeding, post breeding and pre-breeding season of 2013-14 but it was negative allometric for catla and rohu for all seasons while it was isometric for mrigal during breeding and post breeding season and negative allometric during pre-breeding season of 2014-15. According to Mir, *et al.* (2014), Ozaydin *et al.* (2007) and Bagenal and Tesch (1978) regression coefficient ‘b’ unlikely influenced by seasons and habitats. Similarly, in the present study it was also vary from season to season and affected by feeding, sex, maturity, number of specimen, location, degree of stomach fullness, habitat and health. Falaye (2015) concluded adverse aquatic condition of Lekki lagoon and negative allometric growth in *Gymnarchus niloticus* during breeding and post breeding season whereas positive allomeric growth (b=3.3) for pre-monsoon, (b=3.0) for monsoon and (b=3.8) post monsoon were recorded for *Katsuwonus pelamis* from cost of Karachi (Ahmed *et al.* 2012). Similar conclusion was made by Arimoro *et al.* (2007) in *Callinectes amnicola* from Badagry, Lagos State and LawarAre *et al.* (2000) Warri River, Niger Delta (Nigeria).

Establish the relationship between fish length and scale radius is essential to find out the back calculated growth history of fish. The total length of fishes was plotted against scale radius and found that these variables are linearly related which is signifying by correlation coefficient (0.881 to 0.974) and it may be attributed to the availability of food, suitable temperature and favourable aquatic environment. Saddozai *et al.* (2015) reported the weak relationship between total body length and scale radius of *Cirrhinus mrigala* from Tanda dam (Pakistan) whereas high degree of correlation between fish length and scale radius were documented for *Channa marulius* in Harike wetland (Punjab) by Dua and Kumar (2006), for European bitterling from Wieprz-Krzna Canal, (Poland) by Przybylsk and García-Berthou (2004) and for *Labeo rohita* from Jaisamandh lake Rajasthan by Singh *et al.* (1998).

Back-calculation used to generate individual growth histories of fishes (Francis 1990) and proved valuable tool for fisheries scientists and fish ecologists. The average back calculated lengths at different age classes of catla, rohu and mrigal were estimated (Bagenal and Tesch, 1978). In the present study, the observed length and weight of catla, rohu mrigal were in agreement with the back calculated length and weight showing satisfactory growth in initial stages and moderate in subsequent years of life. Present findings are in consonance with the result reported by Ujjania *et al.* (2015) for tilapia from Jaisamand lake, (Rajasthan) and Anderji and Stranai (2013) on *Hucho hucho* from five different rivers of Europe. However, Martinson *et al.* (2000) reported difference in observed length weight and back calculated length weight in Salmon fish from Portland Alaska.

The present study indicated uniformity in growth pattern of studied fishes in Vallabhsagar reservoir, Gujarat (India). The results of two successive years shows that the annual length and weight increment decreases with increase of age might be due to the similar ecological factors and probably a reflection of similar life history traits which was phenotypically same in the respective stocks. Similar observation on catla were documented by Ujjania (2012) from water bodies of southern Rajasthan and by Johal and Tandon (1992) suggested that growth rate of carps is more at the early stage of life.

Index of species average size value is reported less for catla, rohu and mrigal indicating more competition for food and shelter among species.

Ujjania (2012) reported the similar findings within same age group of catla fish from Mahi Bajaj Sagar, Surwania Dam and Aasan pond from southern Rajasthan. Dua and Kumar (2006) evaluate the species average size 14.70 for *Channa marulius* from Punjab whereas Ujjania (2003) reported 12.49 in Tilapia from Jaisamand lake Rajasthan.

The specific rate of linear growth shows declining trend with increasing age without any growth compensation as the growth rate of carps is more at the early stage of life and gradually decreases as the age advances. This observation may be attributed to the availability of space and food for older fishes. Similar observations were reported by Sarang and Sharma (2012) for *Tor khudree* from Jawahar Sagar dam. Singh *et al.* (1998) reported decrease in the specific rate of linear growth with increase of age of rohu from Jaisamandh lake, Rajasthan. Prakash and Gupta (1986) studied comparative growth rates of *C. catla, L. rohita and C. mrigala* of Govindgarh Lake and reported the rapid growth in these species at the first year after that it was diminutive whereas growth increment was maximum in *C. catla,* followed by *L. rohita* and *C. mrigala.*

Analysis of species growth characteristic indicates that three life phases for catla and rohu whereas two life phases for mrigal were existed which shows the growth of fish before sexual maturity and after sexual maturity.

Ujjania *et al.* (2013) demarcated the two growth phases of exotic fish Tilipia from Jaisamand lake whereas Prashant *et al.* (2008) calculate the 3 life phases of catla from Bhagirathi and Satluj river. Ujjania (2003) reported the two growth phases i.e. growth before sexual maturity and growth after sexual maturity for Indian major carps from Mahi Bajaj Sagar, Surwania dam and Aasan pond Rajasthan. Singh *et al.* (1998) studied age and growth of rohu from Jaisamand lake, Rajasthan and reported active growth of fish due to high initial growth constant up to second year of life however, in the subsequent years, i.e. from 2nd to 5th year, the fish has relatively low growth constant distinguished as second growth period. Singh (1990) reported three growth phases in commercially imported riverine fish from Jaisamand Lake. Khan (1972) illustrious the growth of Indian major carps as growth before sexual maturity and growth after sexual maturity from Ganga and Yamuna river from Aligarh, U.P.

Specific rate of weight increase was maximum for catla, rohu and mrigal during initial stages of life and decreases as the age upsurges, while index of population weight growth intensity observed high in mrigal (31.25 and 39.51) followed by rohu (27.09 and 21.69) and catla (22.59 and 20.64) during the study. Present observation may be due to the conducive aquatic environment, less food and place rivalry among intraspecies and interspecies fishes in this water body. These observations are analogous with the observation made by Ujjania *et al. (*2013) for Tilipia fish from Jaisamand lake Rajasthan. Sarang and Sharma (2012) for *Tor khudree* from Jahawar Sagar dam. Prashant *et al.* (2008) reported the specific rate of weight increase was in decreasing trend with increase of age for catla in Yamuna, Bhagirathi and Saryu rivers but it was irregular in case of Ganga river. Whereas Index of population growth intensity of catla from Satluj river is consonance with present study. Similar trends were also observed by Dua and Kumar (2006) in *Channa marulius* from Harike wetland, Punjab.

Condition factor and relative condition factor is an indicator of the variability which attribute to growth coefficient (Balai *et al.* 2017). In the present investigation condition factor and relative condition factor were observed more than one for studied fishes may be due to favourable aquatic condition, ample food availability, good health, growth and gonadal maturity. Gokhale *et al.* (2015) made the observation on condition factor and relative condition factor of rohu catla hybrid fish in Udaisagar Lake and reported the ideal condition of fishes. Sachidanandamurthy and Yajurvedi (2008) reported the relative condition factor >1.0 in catla from two different lake of Mysur. Ujjania (2003) observed the condition factors between 1.77 to1.96 for catla, rohu and mrigal from different water bodies of southern Rajasthan. Observation made by Jain (2000) with respect to condition factor and relative condition factor in Indian major carps in Seliserh reservoir were comparable and supportive to the results of present study. Rajbanshi *et al.* (1984) observed the condition factor and relative condition factor of mrigal from southern Rajasthan similarly Chakraborty and Singh (1963) reported the condition factor and relative condition factor of mrigal and also concluded that it was affected by different growth phases of fish.

Seasonal condition factor (K) and relative condition factor (Kn) values of Indian major carps in Vallabhsagar reservoir were analysed and it was observed that K and Kn was high during the breeding season and post breeding season while low for pre-breeding season. In present observation sexual maturity of fish during breeding season and high deposition of fats during post breeding season may lead to increase the more K and Kn values. Similarly, availability of food and feeding intensity may also affect these biological parameters. Riza *et al.* (2017) reported similar variation in seasonal condition and relative condition for *Acanthopagrus arabicus* from Karachi cost, Pakistan. Zuev *et al.* (2017) investigated the relative condition factor of Arctic Grayling fish from Yenisei River, Russia and recorded maximum during breeding season due to high biomass of benthos and optimum water temperature. Giosa *et al.* (2014) reported low condition factor of *Carassius gibelio* from Poland during summer similarly

Mir *et al.* (2012) reported low K and Kn in *S. curvifrons* species from Jhelum river Kasmir. Ujjania *et al.* (2012) reported the seasonal fluctuation in condition factor and relative condition factor of Indian major carps in Mahi Bajaj Sagar due to gonadal maturity and less feeding intensity.

Gut analysis of catla, rohu and mrigal in Vallabhsagar reservoir revealed that fishes mainly feed on phytoplankton, zooplankton and other assorted items. Findings of present study depict that catla is planktivorous because it primarily feed on zooplankton and phytoplankton whereas rohu is herbivorous because it grazes on phytoplankton and plant material. Mrigal remain omnivorous as it feed on planktons and detritus materials. Khabade (2015) reported that catla and mrigal as omnivorous while rohu as herbivorous fish. Sharda *et al.* (2014) reported carps as herbivorous in nature while cat fishes as carnivorous in feeding behaviour. Food and feeding habit of catla was studied by Kumar *et al.* (2007) from Daya reservoir Rajasthan and categorised it as planktivorous fish. According to Ravindranathan (2003), the major food of the carps consists of planktons, sand, mud, algae and decaying vegetation. However, Yadav (1997) reported that the adult catla feed mainly on algae, crustaceans, some plants, rotifers and insects and hence categorised the same as a plankton feeder. Hora and Pillay (1962) assigned *Catla catla* as a plankton and detritus feeder because it consumes phytoplankton and zooplankton, decayed microvegetation and detritus.

In the present investigation, qualitative changes in food contents during different seasons were not observed whereas quantitative changes in contents were marked due to preference and availability of different food contents in water body. Soni and Ujjania (2017) confirmed the presence of quantitative changes in consumed food contents items of rohu from Vallabhsagar reservoir and absence of qualitative changes. Maheshwari (2015) reported the seasonal variation in gut contents of rohu from Singanallur Lake similarly, Rajanna *et al.* (2015) analysed the feeding behaviour of *Labeo fimbratus* from Vanivalas Sagar (Karnataka) and address the fish as herbivorous. Pradhan and Patra (2015) confirmed the effect of change in water quality on seasonal feeding preference of mrigal from natural lake in Bhuneshwar. Sharda *et al.* (2014) confirmed the seasonal variation in feeding pattern of carp due to overlapping of feeding notches. Joadder (2014) studied the seasonal feeding intensity, percentage of fulness, seasonal pattern of feeding and percentage occurrence of food items in gut of *Labeo bata* from Beels and ponds of Rajshahi area, Bangladesh and confirmed it as herbivorous fish. Manon and Hossain (2011) reported the different life phases for seasonal variation in feeding behaviour of *Cyprinus carpio* from experimental water body of Rajshahi

University, Bangladesh while Joadder and Hossain (2008) concluded that the availability of food was the main reason behind the seasonal feeding variation of *Mugil cephalus* from natural water body of Bangladesh. Kumar *et al.* (2007) observed the gut contains and reported remarkable seasonal feeding difference in rohu from Daya reservoir Rajasthanas, Bhuiyan *et al.* (1999) confirmed the change in food and feeding habit of *Liza parsia* from different water bodies of Bangladesh due to overlapping of food niches.

Feeding intensity of catla, rohu and mrigal in Vallabhsagar were observed and verified by the analysis of gastrosomatic index (GaSI). Study depicts that during spawning season, feeding rate decreases and immediate after spawning it was increases as the fish feeds voraciously to compensate the energy loss during the breeding. Soni and Ujjania (2017) analysed the gastrosomatic index of *Labeo rohita* from Vallabhsagar reservoir and confirmed the variation of feeding intensity due to the maturation of gonad. Similar observations were also documented by Kumar *et al.* (2015) on catla from Udaisagar Rajasthan. Syeda *et al.* (2013) reported lower values of GaSI during spawning periods, higher during post-spawning period followed by pre-monsoon for *Rita rita* from Padda river, Bangladesh. Saikia *et al.* (2012) examine the variation in GaSI of *Channa punctatus* from the Paddy Field of Sivsagar District, Assam and reported it low during spawning season. Sarkar and Deepak (2009) studied the gastrosomatic index of *Chitala chitala* and reported it maximum during pre-monsoon and minimum during monsoon season. Hatikakoty and Biswas (2003) observed the GaSI of Tilapia from subtropical water body and confirmed the seasonal variation due to preference and availability of feed contents. Similar findings were reported by Rao *et al.* (1998) on channa species from East Godavari district (A.P.).