6 RESULTS AND DISCUSSION

6.1 WATER QUALITY ASSESSMENT OF RESERVOIRS

Study of physical and chemical properties of surface water bodies help in understanding the characteristics of the reservoir and their associated biota. Lentic water bodies tend to accumulate more of the nutrients and pollutants compare to lotic water bodies as they lack self-cleaning ability. Catchment geology and morphology, climate and vegetation play an important role in determining the water quality of the reservoir. Increasing anthropogenic activities in and around aquatic system and their catchment area contribute to a large extent in degradation of the water quality. Soil of fine texture having low soil organic matter content are more susceptible to soil erosion. Tilling practices for agriculture make the soil more prone to water and soil erosion (Atreya *et al.,* 2008), as they reduce the infiltration rate thus carrying more of the sediment load into the water body. Livestock grazing breaks up the soil aggregates making it more compact, thus grazing activities in the catchment area further degrade the water and nutrient holding capacity of the soil and increases the soil erosion process (Thapa and Paudel, 2002).

Topology of an area further determines the rate at which the soil get eroded, steep slope may result in an increase in the volume and velocity of surface run-off (Pimentel, 2006). The study primarily aimed at assessing the nutrient dynamics and reciprocal diversity of phytoplankton and avifauna. Thus two major nutrients of aquatic systems, viz., Nitrogen (as Nitrate) and Phosphorous (as Phosphate) were considered for investigation. Furthermore, parameters such as Temperature, pH, Conductivity, Chlorophyll-a, TDS, TSS, TS and chloride which either interact with or be affected by the nutrients were also considered for study. The result of physico-chemical parameters and Chlorophyll - a analysis of water of Timbi, Dhanora and Vadadala have been shown in the graph as the seasonal fluctuation of these parameters.

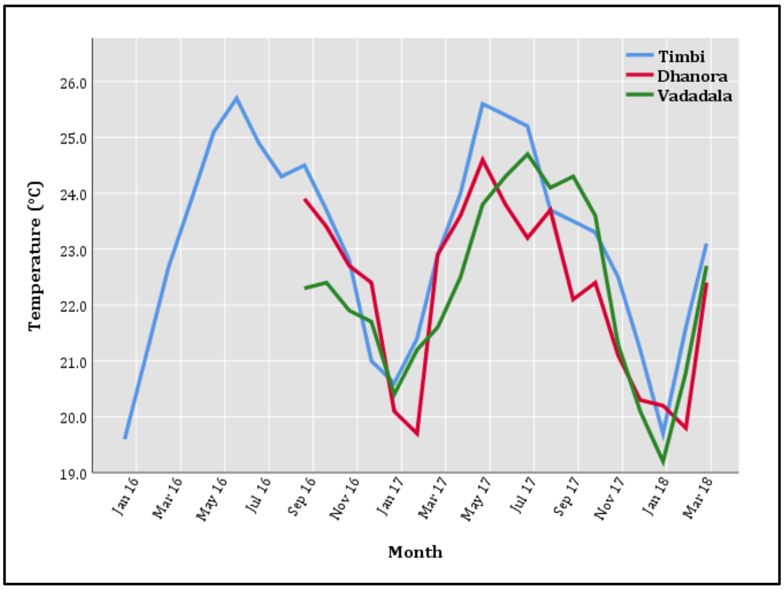

Figure 6.1 Seasonal variation in temperature of water at study sites

The mean temperature at Timbi, Dhanora and Vadadala was 23.1°C, 22.2°C and 22.3°C respectively. The water temperature was maximum in summer and minimum in winter. Temporal variation was similar in all the three reservoirs since they are located in the similar type of climatic conditions (Figure 6.1). Temperature is an important factor in standing waterbody as it controls the planktonic flora (Hutchinson, 1957) and seasonal cycle of phytoplankton (McCambie, 1953). It also influence many physical and chemical characteristics of water like the solubility of oxygen and other gases, chemical reaction rates and microbial activity (Dallas and Day, 2004). Temperature of a waterbody generally depends upon the seasonal variation and fluctuates with changes in the atmospheric temperature, humidity, wind and solar energy (Ingole *et al.,* 2009).

The average pH of water at Timbi, Dhanora and Vadadala were 7.9, 8.0 and 8.1 respectively. pH may vary in a lake/pond due to bedrock, topography and type of anthropogenic activities in the catchment area as it influence the property of run-off. pH plays an important role in the biological process of all the aquatic organisms (Welch, 1952). The summer months showed relatively higher pH during the study period (Figure 6.2). Washing of cloths and aquaculture activities were major anthropogenic interferences with the study sites under investigation. Marginal addition of detergents can be attributed to alkaline pH at the study sites.

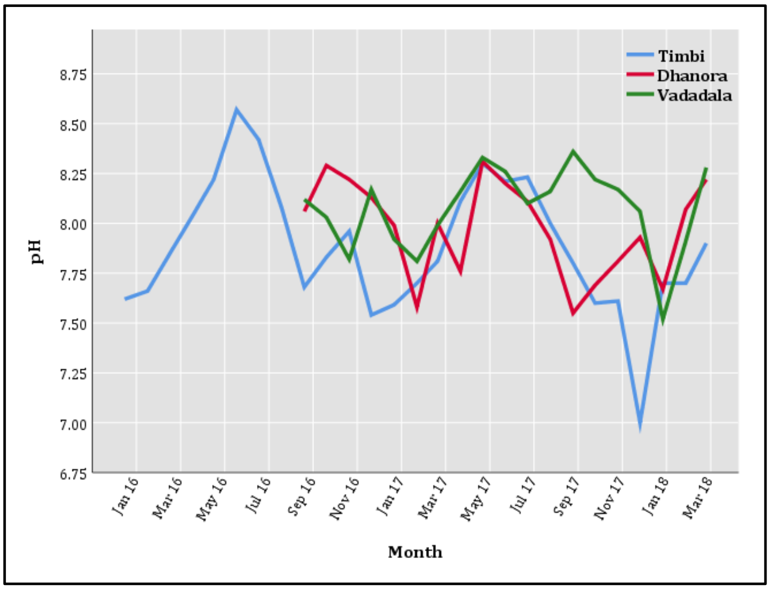

Figure 6.2 Seasonal variation in pH of water at study sites

Figure 6.3 Seasonal variation in Electrical Conductivity of water at study sites

Electrical conductivity is the ability of water to conduct electricity and it signifies the presence of biogenic and abiogenic impurities in the water (Upadhyay *et al.,* 2012). The average EC at the study sides were recorded to be 335.1, 327.3 and 352.4 µS/cm at Timbi, Dhanora and Vadadala respectively. The values of EC of water samples showed increasing trend from summer season and was at peak during the monsoon (Figure 6.3). In summers due to higher evaporation rates, the EC gradually tends to increase and ions entering into the water body by surface runoff during the monsoon justifies the higher EC concentration. The same has been observed in previous studies, too (Kaushik and Saxena, 1999).

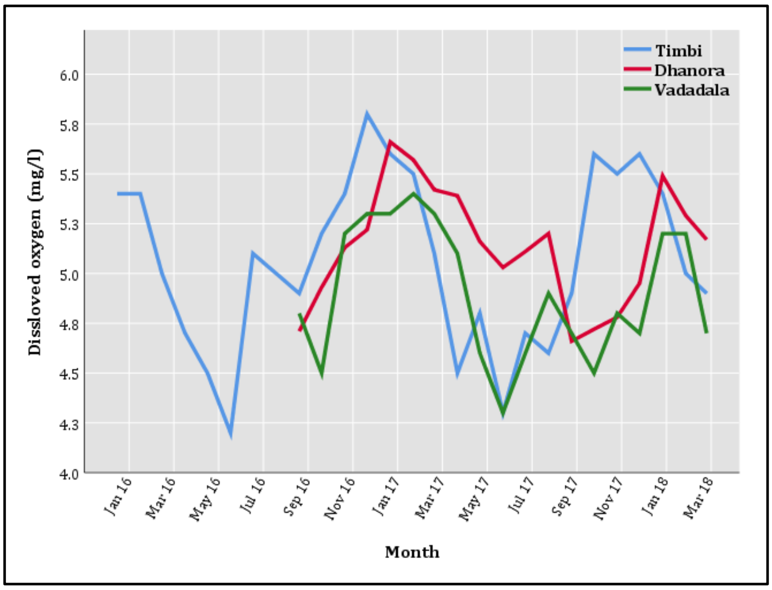

Figure 6.4 Seasonal variation in Dissolved Oxygen of water at study sites

The mean Dissolved Oxygen (DO) at the study sites were 5.1, 5.1 and 4.9 mg/l at Timbi, Dhanora and Vadadala reservoirs. The minimum and maximum values of DO were recorded at Timbi reservoir which were 4.2 mg/l in June, 2016 and 5.8 mg/l in November, 2018. DO of water bodies is one of the essential parameter in aquatic ecosystem. Productivity of an aquatic ecosystem is affected due to fluctuation in the oxygen content as it regulate the solubility and availability of many nutrients (Wetzel, 1983). Graph shows that dissolved oxygen decreases in summer (May 2016, 17) with slight increase after rainy season (July-September) and maximum in winter season (Figure 6.4). Similar type of seasonal variation in dissolved oxygen of lentic waterbodies have also been reported by Thapa (1994), Udash (1996), Shivanikar *et al.,* (1999) and Bhatt *et al.,* (1999). As earlier studies report that decrease in dissolved oxygen during summer might be due to its utilization in the decomposition of organic matter (Bedge and Verma, 1985). Temperature has been found to have positive correlation with phytoplankton (Ranjan *et al.,* 2007), in summer month higher temperature of water favours the growth of phytoplankton thus increasing the productivity of the waterbody resulting in more amount of organic matter. During rainy season, a little increase in the dissolved oxygen might be due to inflow of rain water from surrounding catchment area (Hannan, 1979). More dissolution of gases at colder temperature might be a reason of high dissolved oxygen content in winter season due to high solubility of oxygen.

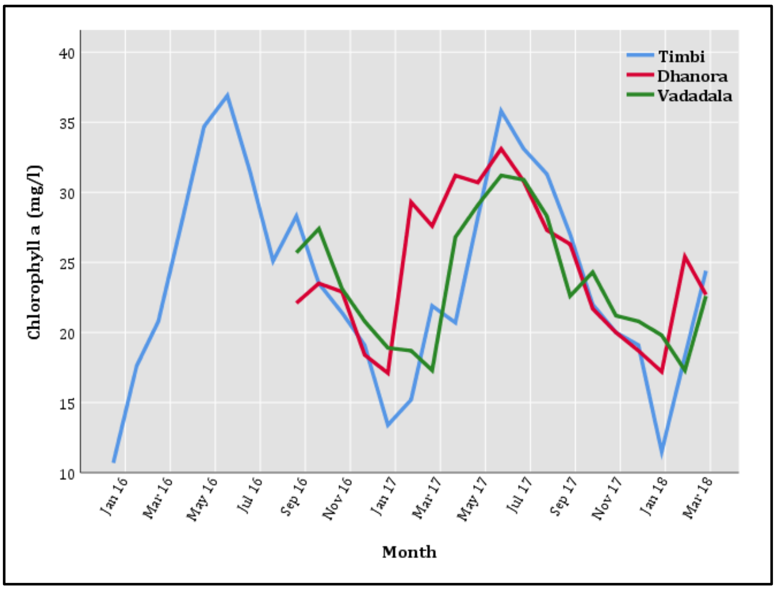

Figure 6.5 Seasonal variation in Chlorophyll a in water at study sites

The average Chlorophyll-a values for Timbi, Dhanora and Vadadala reservoirs were 23.7, 24.7 and 23.8 μg/l respectively. The minimum and maximum concentration of Chl-a of water were recorded at Timbi reservoir. Chl -a measurement in water is an alternative of measurement of phytoplankton biomass which is an important indicator of trophic status in the freshwater (Cottingham and Carpenter, 1998). Human activities in watershed result into increase in nutrient inputs from diffuse sources. The graph for seasonal variation in Chl-a is nearly similar to the graph of temperature variation with maximum concentration in summer season and least in winter (Figure 6.5). In line with the previous studies (Ranjan *et al.,* 2007), the temperature has been found to have positive correlation with phytoplankton in current research work also. Increased nutrient and dissolved oxygen concentration and warm temperature make the water body suitable for the growth of phytoplankton, thus increasing the Chl-a concentration in water.

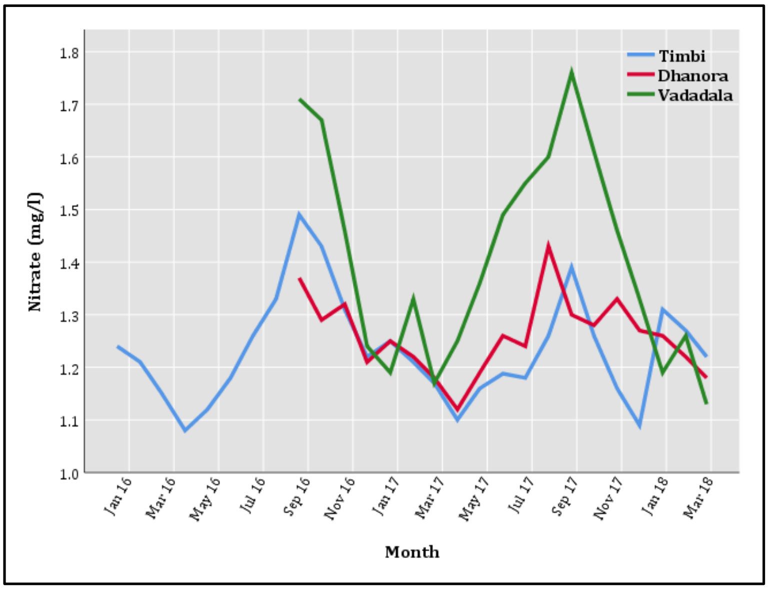

Figure 6.6 Seasonal variation of nitrate concentration in water at study sites

Mean Nitrate concentrations at the study sites were 1.2, 1.3 and 1.4 mg/l in Timbi, Dhanora and Vadadala reservoirs respectively. The minimum and maximum concentration i.e. 1.08 and 1.76 mg/l were recorded at Timbi and Vadadala reservoir resepectively. Moreover, higher concentrations of Nitrate were observed in monsoon which extended upto post-monsoon season. Nitrate intake due to surface runoff from surrounding fields leads to higher concentration during these months (Figure 6.6). In addition to this, lower primary productivity during the winter leads to lower uptake of this nutrient. As summers approach and the temperature rises, the concentration of Nitrate shows a dip when much of the nitrate is trapped in biomass of aquatic plants including phytoplankton. Nitrogen is an important nutrient for aquatic system but when present in excess can cause issues such as eutrophication, algal blooms, anoxic conditions, damage to recreational properties and aesthetics etc. (Lund, 1972; Brezonik and Fulkerson-Brekken, 1998; Randall and Mulla, 2001). The Nitrogen concentration and temporal variability however, do not lead to widespread algal blooms during the study period.

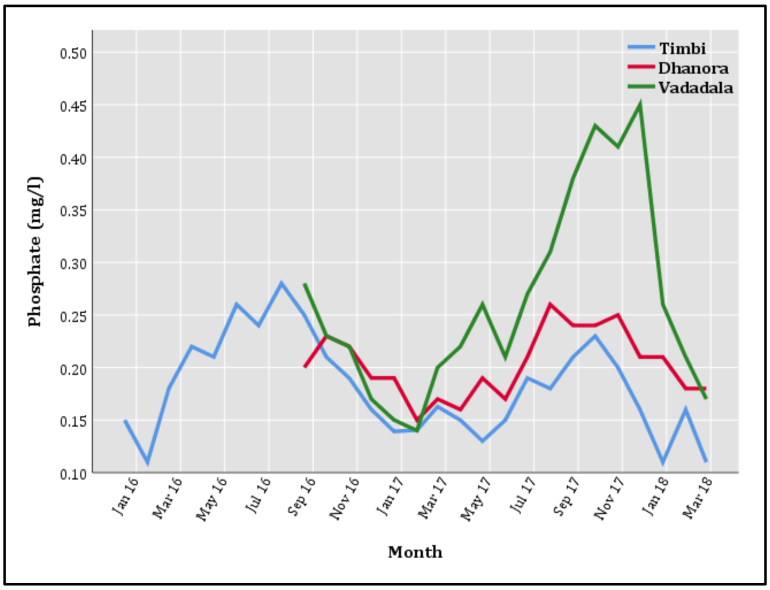

Figure 6.7 Seasonal variation of Phosphate concentration in water at study sites

Average Phosphate concentrations at the study sites were 0.2, 0.2 and 0.3 mg/l in Timbi, Dhanora and Vadadala reservoirs respectively. The minimum concentration of 0.11 mg/l was recorded in Timbi during February, 2016 whereas maximum concentration of 0.45 mg/l was recorded in Vadadala reservoir during December, 2017. Phosphate also showed similar trend in concentration variation to that of Nitrate (Figure 6.7). Both of the nutrients do often act as limiting factor affecting the primary productivity of an aquatic system. In the current study, the water bodies did not show any sign of eutrophication during the study period. Both of the Nutrients (nitrate and phosphate) play very important role in the productivity of such systems. In natural condition, phosphate gets released into the water from weathering of soil at the base as well as through decomposition of organic matter in natural condition. However, in some of the cases, anthropogenic activities have played a major role in deciding their concentration in surface water bodies (Heron, 1961; Dixit *et al.,* 2005; Patil *et al.,* 2012).

Water transparency in lake/reservoir depends upon the type of impurities present in the water. Suspended solids and Dissolved Solids may generate in-situ in the reservoir or may be added from surrounding catchment area through high-flow runoff. Silt and clay particles, organic colloids and phytoplankton contribute to the Total Suspended Solids concentration in the waterbody. Dissolved solids include soluble salts in the form of carbonates, bicarbonates, chlorides, sulphates, phosphate and nitrate of calcium, magnesium, sodium, potassium, iron etc. Excess amount of total dissolved solids may be released in water from the sediments due to change in pH and temperature of water, or may be added along with runoff carrying soluble impurities from the catchment area.

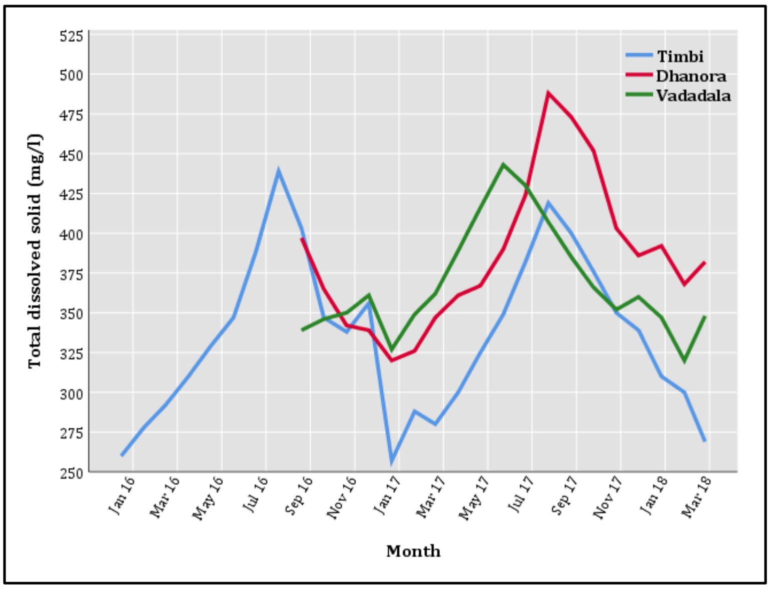

Figure 6.8 Seasonal variation of Total Dissolved Solid concentration in water at study sites

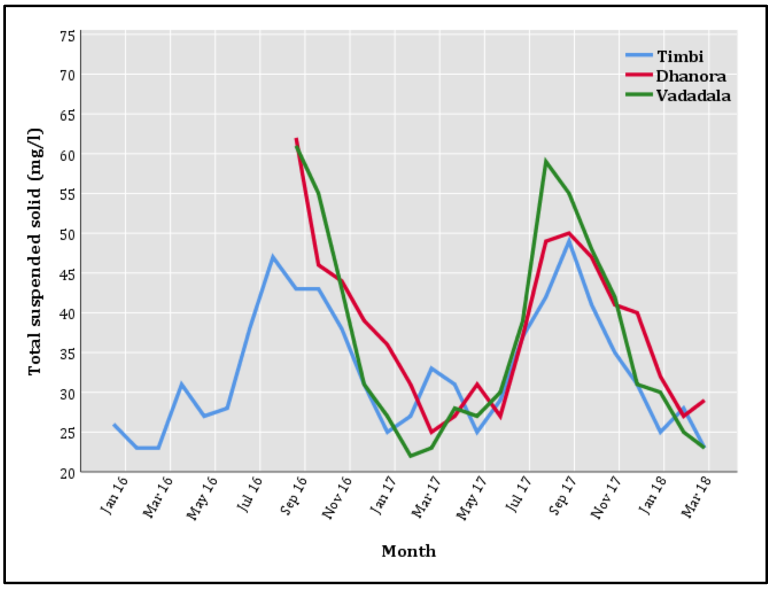

Figure 6.9 Seasonal variation of Total Suspended Solid concentration in water at study sites

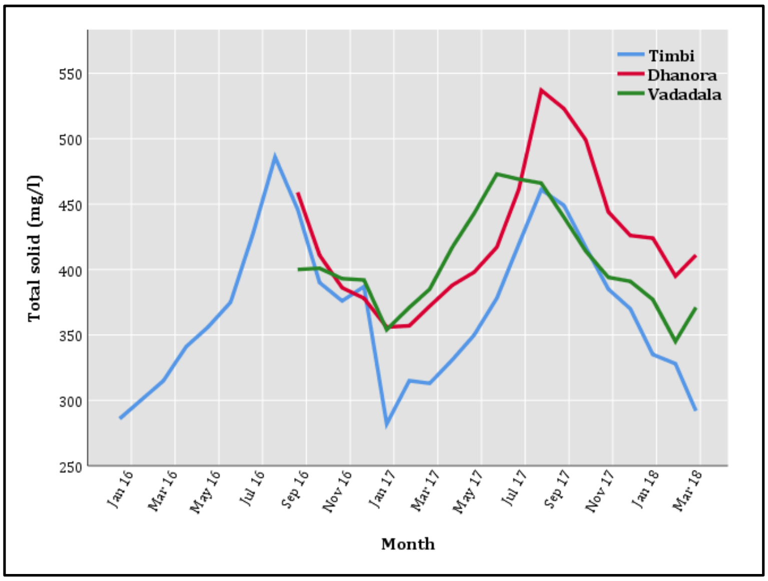

Figure 6.10 Seasonal variation of Total Solid concentration in water at study sites

The graphs (Figure 6.8, 6.9 and 6.10) show higher concentration during the rainy season with subsequent decrease in the winter and pre-monsoon season gradually increasing in rainy and post-monsoon season. This high concentration of total solids (including Total Suspended Solid and Total Dissolved Solids) in monsoon season can be attributed to silt and clay entering the waterbodies with erosive run-off (Ross and Gilbert, 1999).

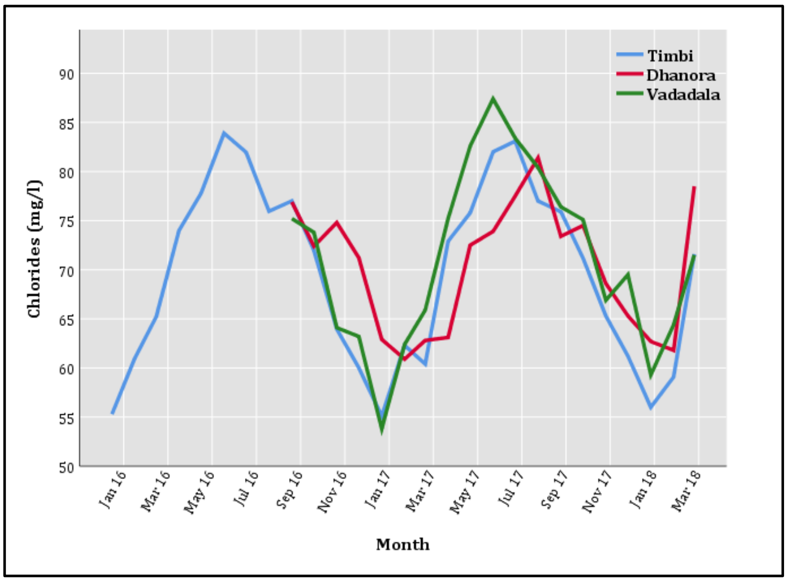

Figure 6.11 Seasonal variation in Chloride concentration of water at study sites

Apart from geogenic sources, chloride may enter into the waterbody through runoff contaminated with fertilizers and animal wastes from surrounding agricultural fields or catchment area. Generally, salts of sodium, potassium and calcium contribute to chloride in water, but increased concentration of chloride is indicator of organic pollution (Venkatasubramani and Meenambal, 2007). The graph (Figure 6.11) shows variation of chloride at all the three sites, with maximum concentration in May-September month. The catchment area at all the three sites are used for agriculture and grazing livestock. Potassium chloride salt is widely used as potash fertilizer for potassium along with Nitrogen and Phosphorous constituents to increase the soil fertility. In rainy season, along with nitrate and phosphate, chloride get dissolved in water and reaches to the reservoir along with the run-off.

6.1.1 Multivariate Analysis

Water quality parameters were analysed using bivariate and multivariate analysis techniques with the help of Microsoft excel and SPSS. To identify the correlation within parameters Pearson correlation statistics was used. All errors were calculated at 95% and 99% confidence level. Table 6.1 provides Pearson correlation coefficients for all the parameters to determine the general inter-relationship between them. Pearson value more than and less than 0.6 indicates strong positive and negative correlation. Parameters like pH, EC, Chl-a and chloride have strong positive correlation with temperature, while negative correlation of Dissolved oxygen with temperature indicates simultaneous decrease with increase in temperature. Phosphate and nitrate show positive correlation which may be attributed to the common source of these elements into the water bodies. As all three wetlands are surrounded by agricultural fields, runoff from these fields containing excess of fertilizers may increase the concentration of nitrate and phosphate into these sites. Chloride shows strong correlation with most of the parameters except nitrate, phosphate and Total Suspended Solids. Total solids in water is sum total of total suspended solid and total dissolved solids, and Pearson correlation coefficient is significantly positive for these parameters apparently due to their arithmetic relation. The main contributing factor to Total Solids can be interpreted from the correlation coefficient calculated for each wetland (Table 6.2). In Dhanora and Timbi reservoir, TDS and TSS have equal contribution to Total solids while in the case of Vadadala reservoir TSS is least contributor to total solids indicating relatively high TDS. The same is supported by the correlation coefficient values between the variables (Table 6.2). It indicates that in Vadadala, runoff carry much of the soluble salt along with it from the catchment area increasing the concentration of total dissolved solids in water. In Dhanora wetland, nitrate and phosphate show strong correlation with TSS with values of 0.801 and 0.702 respectively; in Timbi only phosphate shows high correlation with both TDS (0.712) and TSS (0.696). In case of Vadadala nitrate have very strong correlation with TSS of 0.900 while phosphate is not having significant correlation with either TDS or TSS. This difference in correlation coefficient values at each site may be because of different type of agricultural activities and fertilizers used in the periphery of these reservoirs, which directs to further investigation in the subject. It is important to note that chlorophyll a does not show any correlation in Dhanora wetland, but it has significantly positive correlation with temperature, pH, EC and chloride in Timbi reservoir, while in Vadadala reservoir it shows positive correlation with temperature, EC, TDS, TS and chloride. This indicates that water of Timbi and Vadadala reservoir favours the growth of phytoplankton.

Table 6.1 Pearson correlation between water quality parameters

Pearson Correlation											
	Temperature	pH	EC	DO	Chl-a	Nitrate	Phosphate	TDS	TSS	TS	Chloride
Temperature	1	0.583**	0.626**	-0.596**	0.759**	0.127	0.139	0.331**	0.249*	0.343**	0.812**
pH		1	0.416**	-0.602**	0.541**	0.223	0.331**	0.203	0.141	0.209	0.654**
EC			1	-0.527**	0.548**	0.558**	0.463**	0.607**	0.628**	0.662**	0.722**
DO				1	-0.579**	-0.322**	-0.424**	-0.313*	-0.306*	-0.338**	-0.734**
Chl-a					1	0.105	0.179	0.451**	0.178	0.437**	0.755**
Nitrate						1	0.621**	0.341**	0.730**	0.445**	0.346**
Phosphate							1	0.424**	0.558**	0.486**	0.396**
TDS								1	0.487**	0.986**	0.606**
TSS									1	0.626**	0.427**
TS										1	0.622**
Chloride											1
**. Correlation is significant at the 0.01 level (2-tailed).											
*. Correlation is significant at the 0.05 level (2-tailed).											

Table 6.2 Wetland wise Pearson correlation among water quality parameters

Pearson Correlation (wetland codes –Dh: Dhanora, Ti:Timbi, Va: Vadadala)												
		Temperature	pH	EC	DO	Chl-a	Nitrate	Phosphate	TDS	TSS	TS	Chloride
	Temperature	1	0.483*	0.556*	-0.361	0.521*	0.08	0.106	0.27	0.221	0.283	0.676**
	pH		1	0.319	-0.016	0.11	-0.077	-0.138	-0.325	-0.1	-0.309	0.386
	EC			1	-0.659**	0.086	0.655**	0.596**	0.516*	0.699**	0.593**	0.833**
	DO				1	0.046	-0.495*	-0.610**	-0.615**	-0.674**	-0.676**	-0.587**
	Chl-a					1	-0.259	-0.348	0.128	-0.337	0.051	0.155
Dh	Nitrate						1	0.771**	0.566*	0.801**	0.657**	0.511*
	Phosphate							1	0.711**	0.702**	0.767**	0.515*
	TDS								1	0.496*	0.986**	0.596**
	TSS									1	0.632**	0.552*
	TS										1	0.637**
	Chloride											1
	Temperature	1	0.785**	0.722**	-0.776**	0.928**	-0.046	0.556**	0.530**	0.354	0.516**	0.944**
	pH		1	0.387*	-0.778**	0.736**	-0.107	0.338	0.242	0.049	0.22	0.757**
Ti	EC			1	-0.436*	0.727**	0.438*	0.713**	0.886**	0.761**	0.886**	0.788**
	DO				1	-0.790**	0.177	-0.263	-0.216	-0.034	-0.195	-0.768**
	Chl-a					1	-0.069	0.531**	0.566**	0.316	0.543**	0.937**

	Nitrate						1	0.296	0.421*	0.594**	0.453*	0.031
	Phosphate							1	.712**	0.696**	0.723**	0.580**
	TDS								1	0.837**	0.997**	0.637**
	TSS									1	0.876**	0.421*
	TS										1	0.620**
	Chloride											1
	Temperature	1	0.748**	0.669**	-0.649**	0.783**	0.605**	0.151	0.749**	0.421	0.841**	0.872**
	pH		1	0.524*	-0.649**	0.535*	0.401	0.317	0.479*	0.296	0.548*	0.706**
	EC			1	-0.527*	0.606**	0.743**	0.272	0.490*	0.614**	0.675**	0.559*
	DO				1	-0.736**	-0.601**	-0.509*	-0.523*	-0.429	-0.637**	-0.812**
	Chl-a					1	0.568**	0.144	0.733**	0.455*	0.840**	0.887**
Va	Nitrate						1	0.517*	0.264	0.900**	0.572**	0.586**
	Phosphate							1	0.135	0.502*	0.308	0.306
	TDS								1	0.034	0.930**	0.794**
	TSS									1	0.398	0.396
	TS										1	0.874**
	Chloride											1

*. Correlation is significant at the 0.05 level (2-tailed).; **. Correlation is significant at the 0.01 level (2-tailed).

Table 6.3 Analysis of Variance (ANOVA) for comparing water quality parameters among wetlands

	ANOVA	**Dhanora**			**Timbi**			**Vadadala**		
Parameters	F	Mean	Lower	Upper	Mean	Lower	Upper	Mean	Lower	Upper
Temperature	1.964	22.2	21.5	23	23.1	22.4	23.8	22.3	21.6	23
pH	3.22*	8	7.9	8.1	7.9	7.7	8	8.1	8	8.2
EC	1.38	327.3	308.4	346.2	335.1	313	357.3	352.4	331	373.7
DO	2.331	5.1	5	5.3	5.1	4.9	5.2	4.9	4.7	5
Chl-a	0.129	24.5	22.1	27	23.7	20.8	26.5	23.8	21.7	25.8
TDS	-	385.4	362.8	408	334.5	314.7	354.2	367.3	351.4	383.1
TS	7.60**	423.3	397.9	448.6	367	344.7	389.4	405	387.8	422.2
Chloride	0.292	70.3	67.1	73.4	69.5	65.9	73.1	71.4	67.3	75.5
Nitrate	12.47**	1.3	1.2	1.3	1.2	1.2	1.3	1.4	1.3	1.5
Phosphate	10.68**	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.3
TSS	-	37.9	33.1	42.7	32.6	29.5	35.6	37.8	31.4	44.1
** $p<0.001$, * $p < 0.05$										

Table 6.4 Post-hoc analysis

Multiple Comparisons						
Parameter	Post-hoc test	I	J	Mean Difference (I-J)	Std. Error	Sig.
pH	Tukey HSD	Dhanora	Timbi	.096	.081	.471
			Vadadala	-.108	.087	.436
		Timbi	Dhanora	-.096	.081	.471
			Vadadala	-.203	.080	.036
		Vadadala	Dhanora	.108	.087	.436
			Timbi	.203*	.080	.036
TS	Tukey HSD	Dhanora	Timbi	56.226*	15.027	.001
			Vadadala	18.263	16.077	.496
		Timbi	Dhanora	-56.226*	15.027	.001
			Vadadala	-37.963*	14.805	.034
		Vadadala	Dhanora	-18.263	16.077	.496
			Timbi	37.963*	14.805	.034
Nitrate	Games-Howell	Dhanora	Timbi	.028	.025	.522
			Vadadala	-.158	.047	.007
		Timbi	Dhanora	-.028	.025	.522
			Vadadala	-.186	.048	.002
		Vadadala	Dhanora	.158*	.047	.007
			Timbi	.186*	.048	.002
Phosphate	Games-Howell	Dhanora	Timbi	.022	.012	.154
			Vadadala	-.060	.022	.028
		Timbi	Dhanora	-.022	.012	.154
			Vadadala	-.082	.022	.003
		Vadadala	Dhanora	.060*	.022	.028
			Timbi	.082*	.022	.003
*. The mean difference is significant at the 0.05 level.						

To compare the water quality

parameter of wetlands, ANOVA test was run (Table 6.3). ANOVA test is incorporated to know if there is significance difference between the means of the variables under investigation. The results show indicate no significant difference in the means of Temperature, EC, DO, Chlorophyll – a and Chloride. The same test also indicate that the mean concentration of pH, Total solids, Nitrates and Phosphate in water significantly different in wetlands ($p<0.05$). Since the test was run for three sites simultaneously, even though significant difference was identified, it was unclear that the difference in between any two or all the three reservoirs with respect to the parameters. Thus, further analysis was warranted where paired tests to be conducted to add clarity to the results. For the same reason, post – hoc analysis was carried out. Post-hoc analysis indicates that, while level of pH of Dhanora wetland is similar to that of Vadadala and Timbi ($p>0.05$). The pH of Timbi and Vadadala is significantly different from each other and pH of Vadadala is higher than that of Timbi ($p< 0.05$). In case of Total solids Vadadala and Dhanora wetland have significantly higher concentration than Timbi ($p<0.05$) (Table 6.4). Comparing the nutrient concentration across wetlands it was found out that, Vadadala wetland is nutrient rich in terms of Nitrate and phosphate concentration than Timbi and Dhanora. Surrounding agricultural fields as non-point sources of nutrients can be one of the cause for relatively higher nutrients in Vadadala reservoir.

6.2 ANALYSIS OF LAKE SEDIMENT

The sediment quality in all the three study sites didn't show significant variation. Minor variation in the sediment quality occurred during pre-monsoon and post-monsoon Seasons (Annexure I). The Minimum and Maximum values of Temperature were 21.3°C and 24.9°C, where the lower temperatures were observed during the post monsoon season at all the three study sites. The pH range of 7.55 to 8.16 indicate that the sediment extract was on the alkaline side throughout the study period. This may be attributed to the detergents and soaps used for bathing and washing activities at the study sites. It is evident from the previous studies, that at alkaline pH, the Phosphorous release from the sediments to the water column is higher (Christophoridis and Fytianos, 2006). At all the three study sites, thus, P availability in the water would not be a limiting factor. The electrical conductivity ranged from 317 µS/cm to 412 µS/cm and relatively higher values of the same were recorded during the pre–monsoon season. Similar trends were observed in water soluble ionic nutrients such as Nitrate and Phosphate, though the fluctuations were not drastically high. Organic Carbon and Organic Matter content also remained relatively stable during the study period except for a partially higher concentration during the pre–monsoon season. Trends in the concentrations in the sediment quality parameters are displayed as line graphs below (Figure 6.12- 6.18).

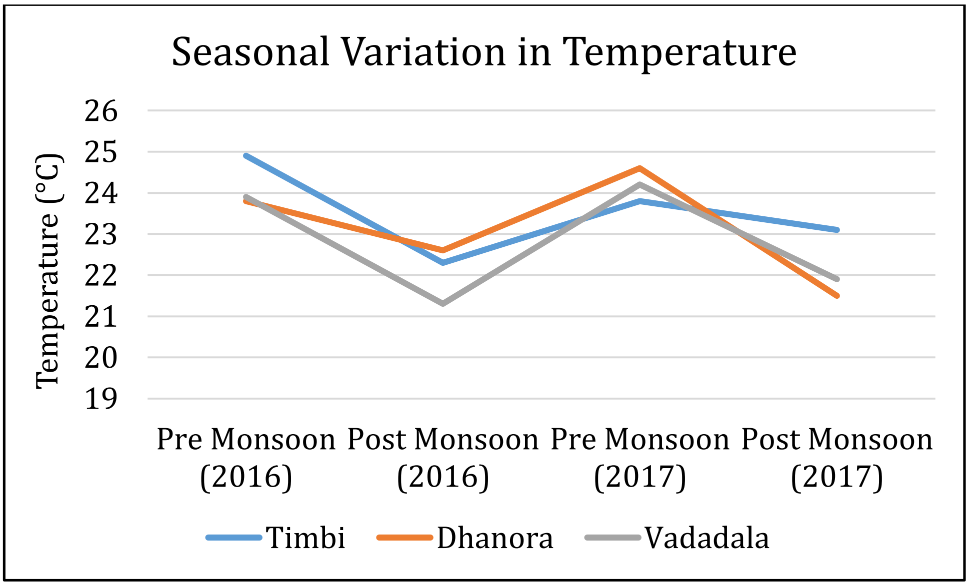

Figure 6.12 Seasonal trend in Sediment temperature at study sites

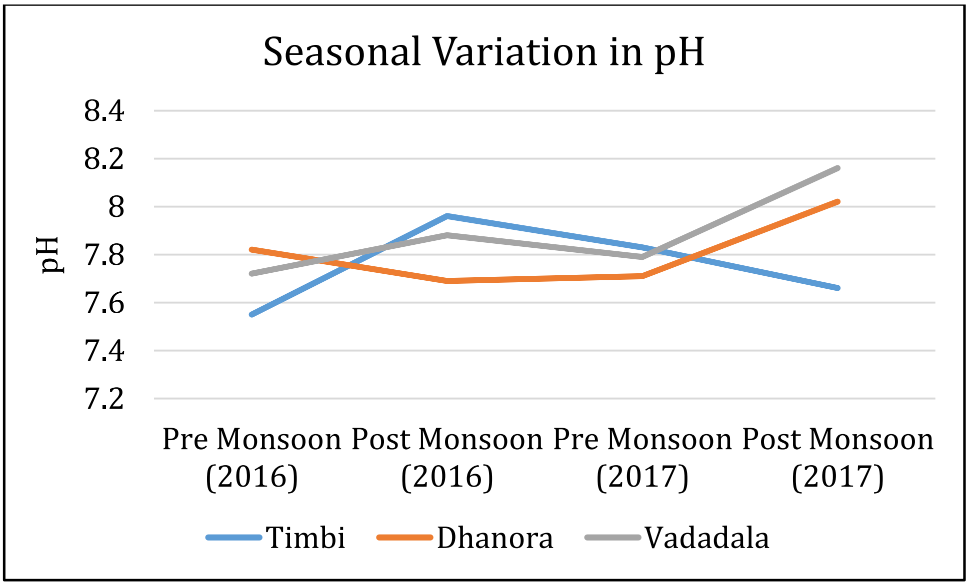

Figure 6.13 Seasonal trend in pH at study sites

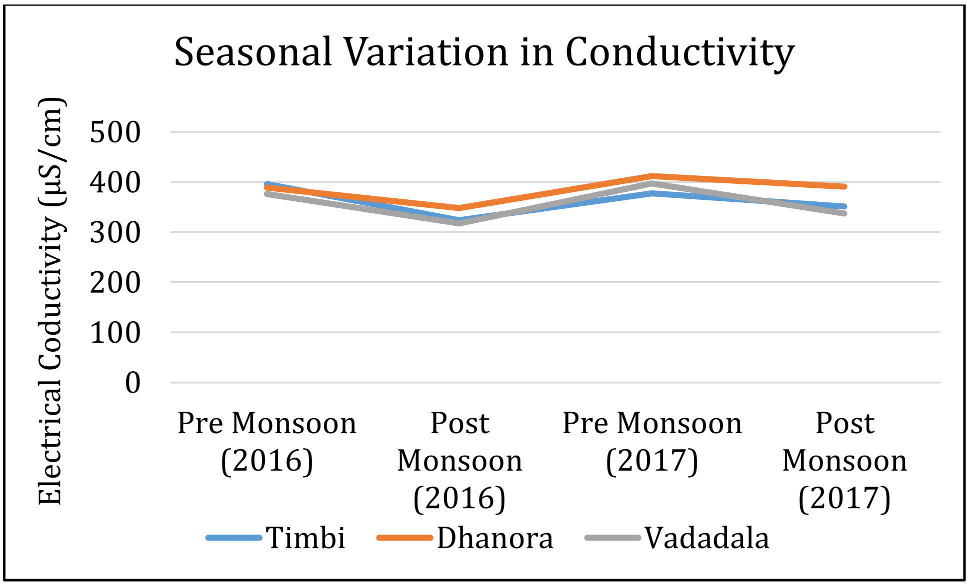

Figure 6.14 Seasonal trend in Electrical Conductivity at study sites

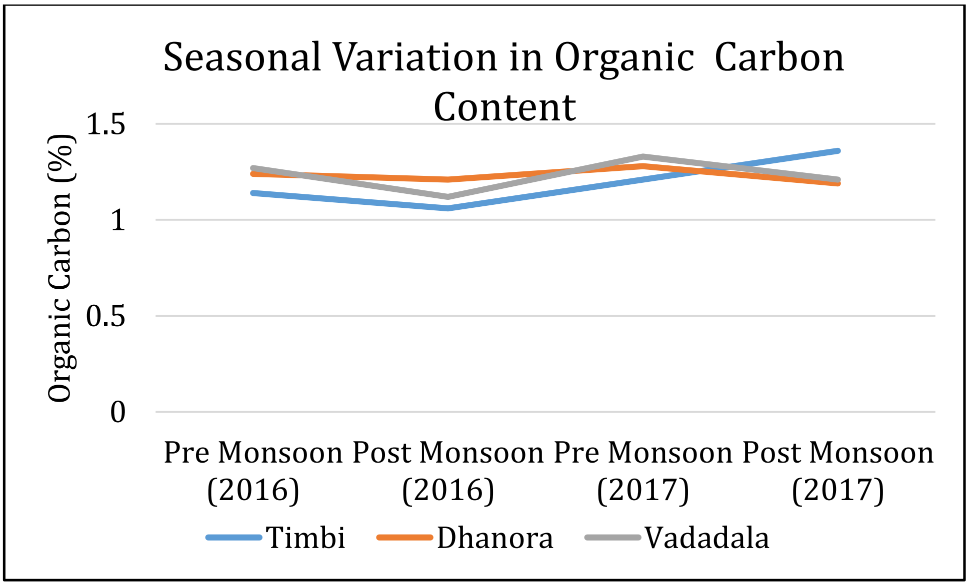

Figure 6.15 Seasonal trend in Sediment Organic Carbon content at study sites

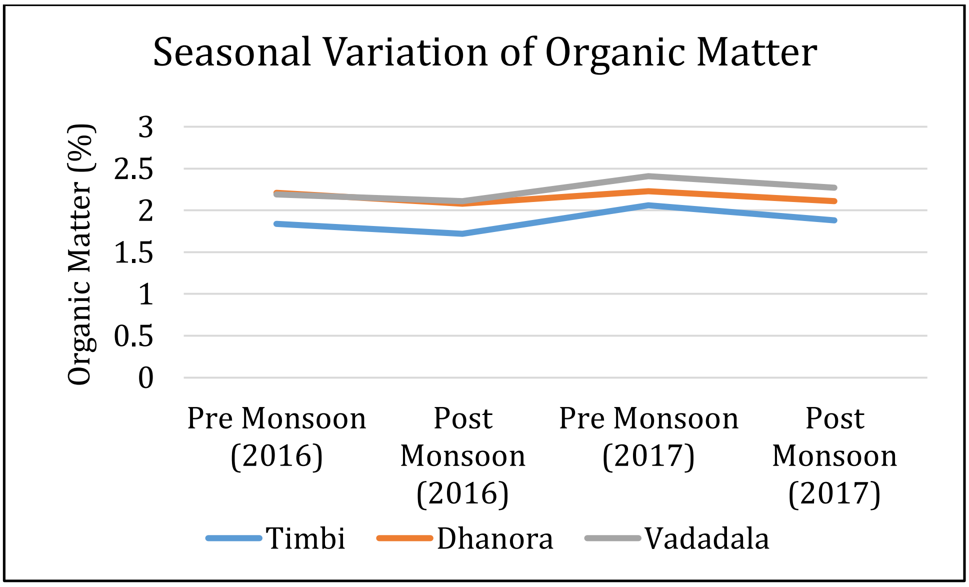

Figure 6.16 Seasonal trend in Sediment Organic Matter content at study sites

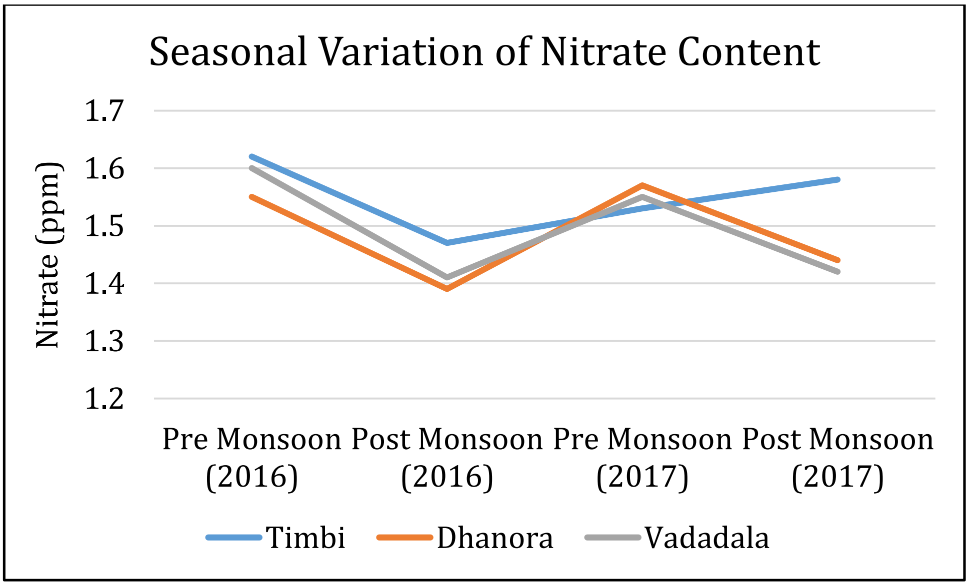

Figure 6.17 Seasonal trend in Sediment Nitrate content at study sites

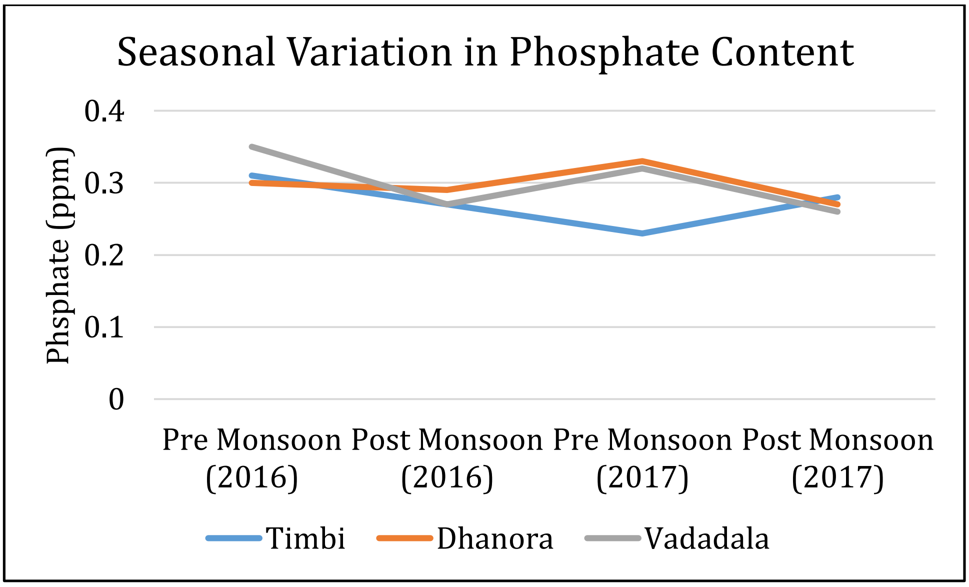

Figure 6.18 Seasonal trend in Sediment Phosphate content at study sites

Partially lower concentrations in water soluble elements might be attributed to re-suspension during the monsoon season due to the currents of inflow of water. The water currents generated by the wind also cause re-suspension of sediments and deposited nutrients into the water column near water sediment interface. This is evident in shallow lakes and reservoirs where thermocline is absent and bottom sediments are recirculated with water currents (Qin *et al.,* 2004). This continuous mixing may cause homogenization of properties such as pH, Electrical conductivity, water soluble nutrients and other water soluble ions. The average temperature and pH of water and sediments remained similar for all the study sites during the study period (Table 6.5). There was no notable difference identified in the mean Electrical Conductivity. In case of Nutrients, relatively higher concentrations were observed in sediments than in water. This may be attributed to partial re-suspension of nutrients in the water column. It is to be noted that the sediments were collected from upto a depth of 15 cm and homogenized before analysis and the results were displayed as an average concentration of element/compound of the same. It is also to be noticed that the deeper parts of the sediments do not directly interact with the above lying water and thus, delivery of nutrients to the water column may not be possible unless the sediments are vigorously disturbed. During the study period, no such event was observed, thus, the higher concentration of Nitrate and Phosphate in sediments in comparison to the water can be justified.

Table 6.5 Average values of selected Water Quality Parameters (WQP) and Sediment Quality Parameters (SQP) at different study sites

	Timbi		**Vadadala**		**Dhanora**	
Parameter	**WQP**	**SQP**	**WQP**	**SQP**	**WQP**	**SQP**
Temperature (°C)	23.08	23.53	22.35	22.83	22.16	23.13
pH	7.88	7.75	8.07	7.89	8.00	7.81
EC (µS/cm)	335.11	362.00	341.30	356.75	328.93	385.00
Nitrate (mg/l)	1.23	1.55	1.37	1.50	1.27	1.49
Phosphate (mg/l)	0.18	0.27	0.26	0.30	0.20	0.30

The concentrations of Nitrate and Phosphates both in water and sediment did not show drastic increase or decrease during the study period. This indicates that homeostasis exists between the sediment and above lying water with respect to nutrients. This can be considered to be an indirect evidence of these water bodies to be stable ecosystems with respect to nutrient enrichment and thus, there are lesser possibilities of these sites to turn into eutrophicated bodies unless enormous quantities of nutrient input takes place.

6.3 PHYTOPLANKTON DIVERSITY

The sites were investigated to study the phytoplankton diversity. 'Sedgwick rafter cell chamber' was used and the concentrated sample flooded the chamber with numerous planktonic cells (Figure 6.19– 6.23). The total number of phytoplankton species encountered during the study was 30, belonging to 5 different classes namely Chlorophyceae, Bacillariophyceae, Cyanophyceae, Euglenophyceae and Chrysophyceae. Out of these, 24 species were found in 'Timbi' followed by 22 species in 'Dhanora' and 17 species in 'Vadadala' reservoir. Chlorophyceae was most abundant group followed by Bacillariophyceae and Cyanophyceae at all the three reservoirs except Vadadala where Chlorophyceae and Bacillariophyceae showed equal number of species (Figure 6.24 - 6.26).

Chlorophyceae, often referred to as green algae, is a major group of microalgae and they have much wider ecological amplitude. Different species belonging to Chlorophyceae may be found as unicellular organisms as well as appear as colonies. There are also a number of species which are filamentous or have more complex structures. Cells of Chlorophyceae are found in aquatic systems ranging from lentic freshwater systems, to river and streams, brackish water as well as saline waters of seas and oceans. Due to their diversified adaptability, they are generally the most abundant group of phytoplankton found in majority of the aquatic systems. Bacillariophyceae, also known as diatoms have mammoth contribution in the global primary productivity and are important part of the aquatic food web. All the three reservoirs considered for study showed their abundance which indicates fair availability of nutrients and healthy state of primary productivity.

The Cyanophyceae, alternatively called as *Blue-green* algae have affinity towards a set of conditions characterised by high concentration of nutrients, stagnant water system and very often warm water temperatures. All the three reservoirs did not show a sign of nutrient scarcity and due to shallow depths, the water temperature remained comfortably high for the growth of Cyanophyceae. However, unlike Chlorophyceae and Bacillariophyceae, Cyanophyceae has multiple nuisances attached to them. They are responsible for algal blooming, alter the odour and taste of the water and are also known to produce cyanotoxins causing a number of health issues (Meriluoto *et al.,* 2005). When these blooms die and decompose, they cause oxygen depletion and lead to anoxic conditions leading to death of fishes. This is the reason why lake/reservoir management practices should involve management of *Blue-green* algae.

Euglenophyceae are largely found in the freshwater bodies but some members are also found in other aquatic habitats. They are most common inhabitant of wetland such as marshes, swamps, bogs, etc. These species are often associated with the habitats characterized by high organic matter content as well as high concentration of nutrients (Van Vuuren *et al.*, 2006). In the current study, two species of Euglenophyceae viz., *Euglena sp*. and *Phacus sp*. were encountered (Annexure II).

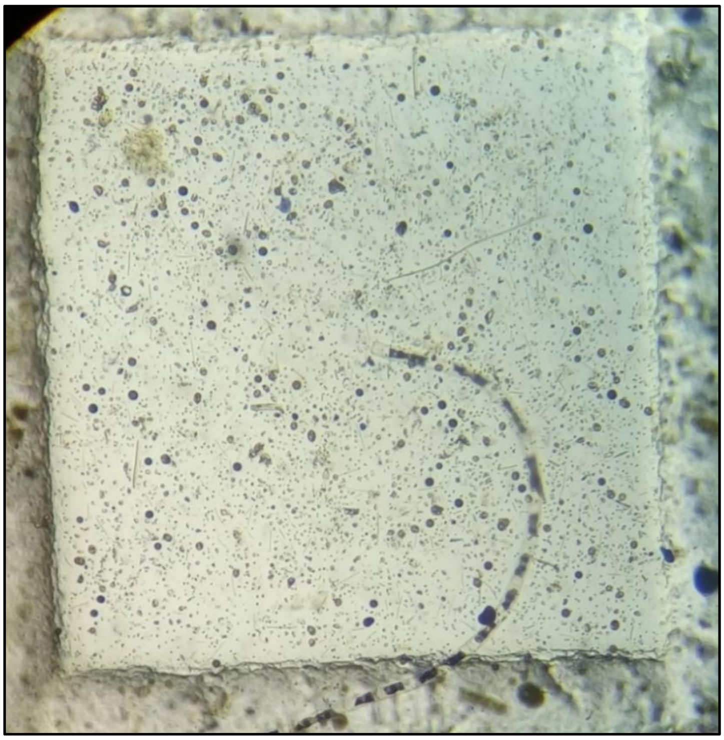

Figure 6.19 Microscopic field of a Sedgwick Rafter cell containing numerous planktonic cells

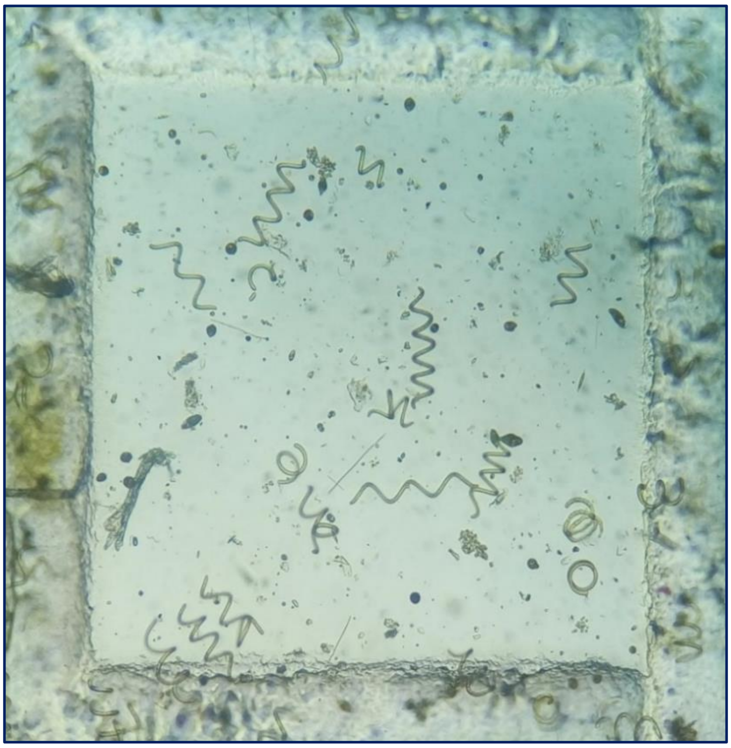

Figure 6.20 Multiple strands of *Spirulina* sp. (Class: Cyanophyceae)

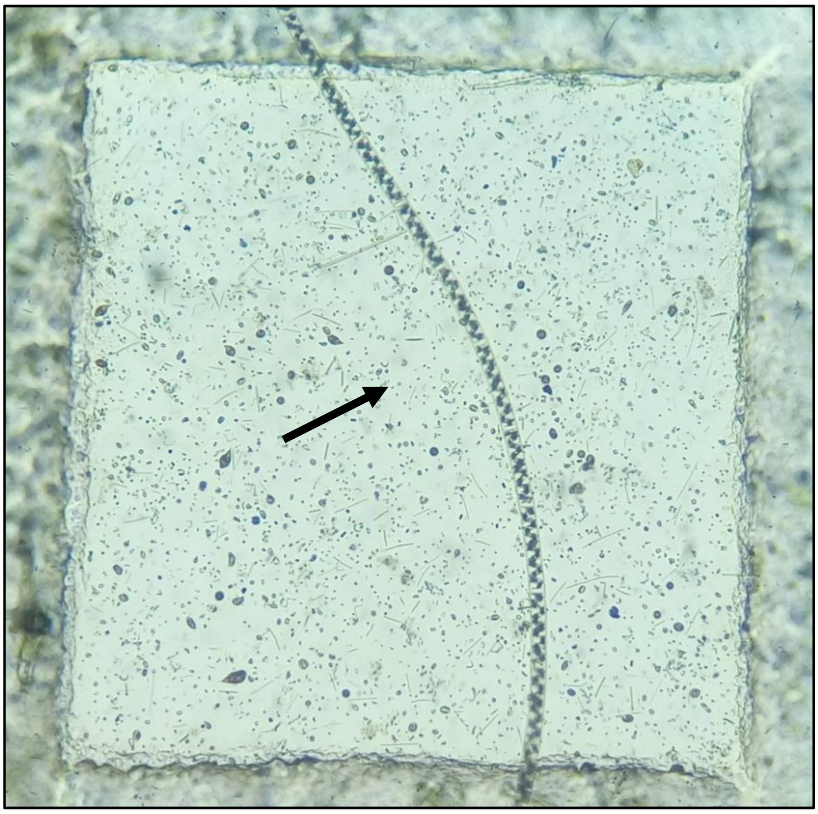

Figure 6.21 *Spirogyra* sp. (Class: Chlorophyceae)

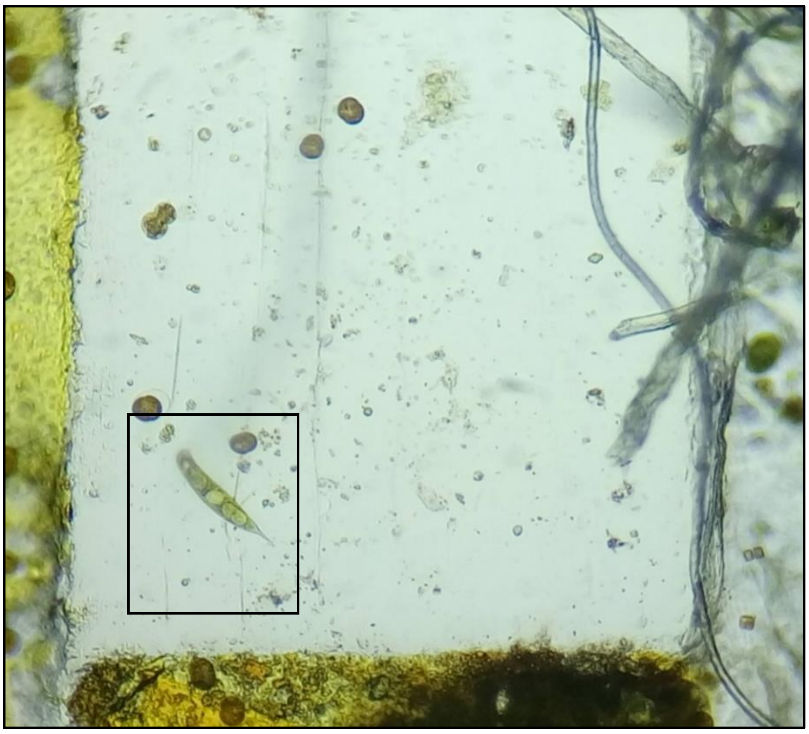

Figure 6.22 *Euglena* sp. (Class: Euglenophyceae) (within the box)

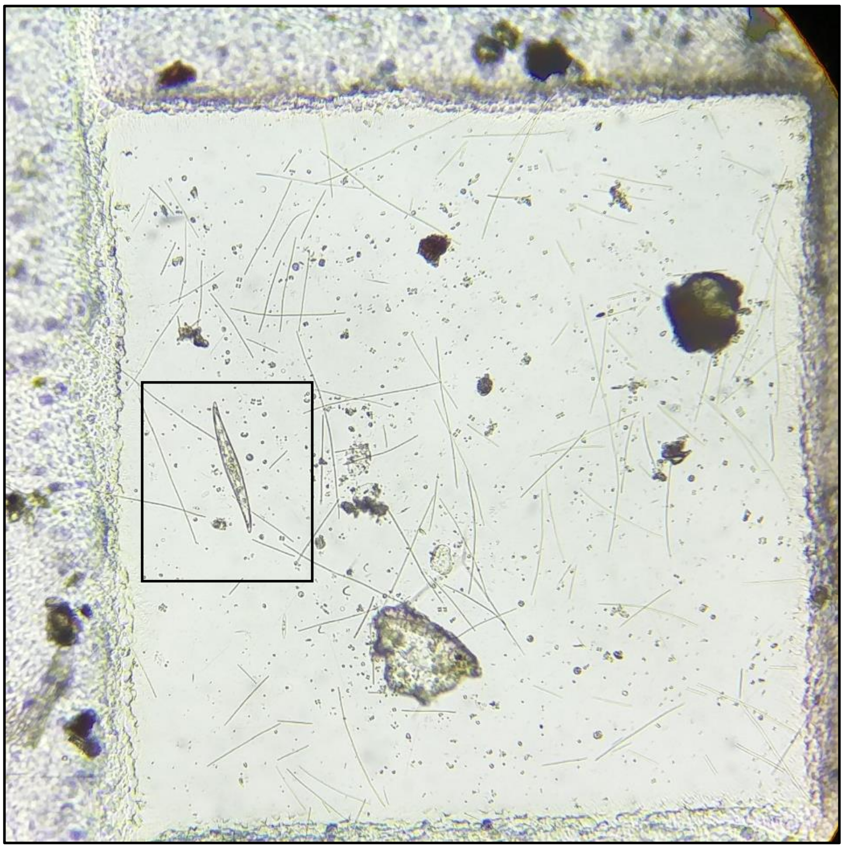

Figure 6.23 *Pleurosigma* sp. (Class: Bacillariophyceae) (within the box)

Each reservoir had presence of at least one species of Euglenophyceae which indicates nutritional and organic carbon availability. *Mallomonas sp.* belonging to Class Chrysophyceae was only present in Timbi reservoir and was absent in the remaining two. The characteristic habitat requirement for *Mallomonas* sp. is shallow ponds instead of rivers and streams. They are often common in highly vegetated sites (Silver *et al*., 1994). Thus, this can be attributed to areas of Timbi reservoir characterized by abundance of macrophytes growth (Figure 6.27). They prefer the aquatic systems having partially acidic pH with moderately low concentration of nutrients. Presence of *Mallomonas* sp. in Timbi reservoir is thus, indicative of oligotrophic to mesotrophic status.

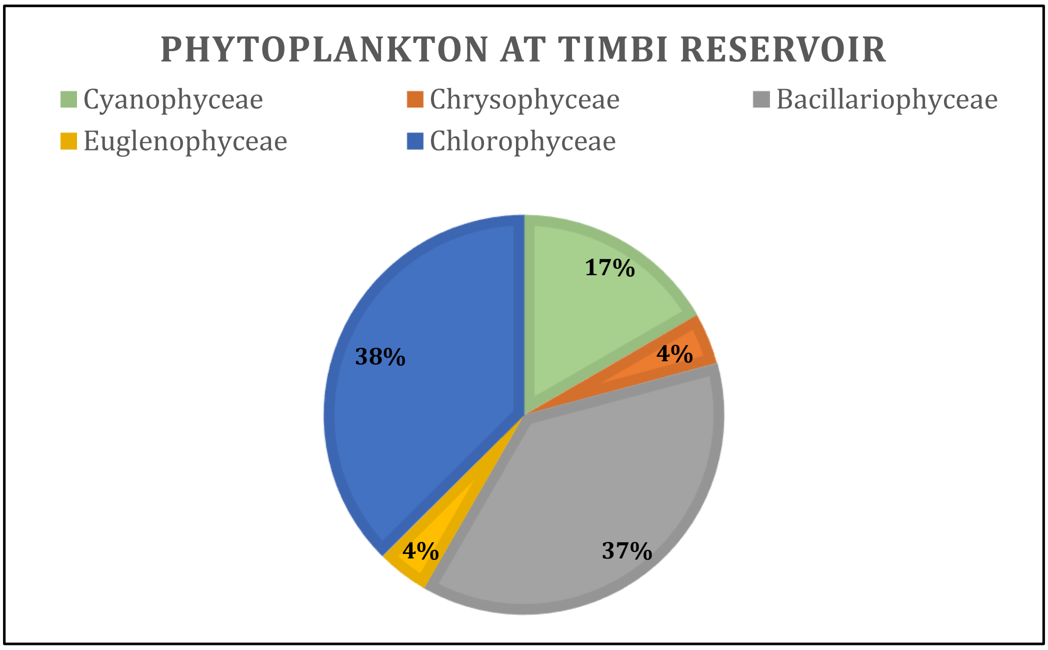

Figure 6.24 Class wise Phytoplankton composition at Timbi reservoir

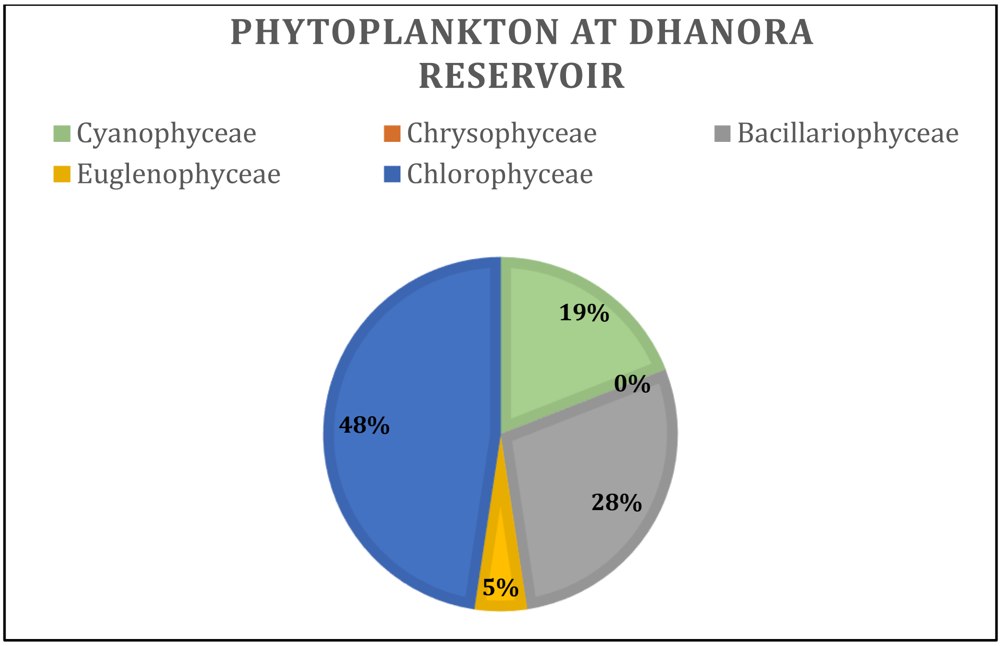

Figure 6.25 Class wise Phytoplankton composition at Dhanora reservoir

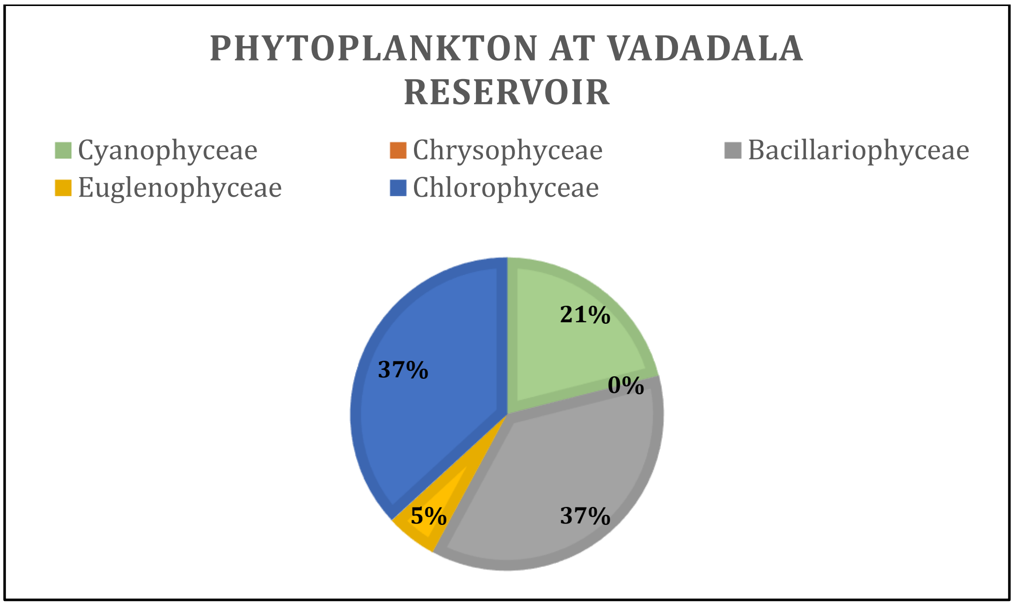

Figure 6.26 Class wise Phytoplankton composition at Vadadala reservoir

Figure 6.27 Abundant Macrophytes at Timbi Reservoir

In a couple of studies aimed towards diversity studies in a freshwater reservoir with respect to phytoplankton it was found that the Chorophyceae were the most abundant Class (Bhat *et al.,* 2012; Laskar and Gupta, 2013). However, in one of the sacred reservoir, the study team found Bacillariophyceae to be abundant followed by Chlorophyceae and Cyanophyceae. They also found Euglenophyceae present in the water samples. This might be due to excess organic load added to the water body in the form of flowers, leaves etc. organic material used for worship (Soni and Thomas, 2013). In the current study at least one species belonging to Class Euglenophyceae was present in all the three reservoirs. Previous studies indicate that presence of Euglenophyceae is indicative of organic pollution (Kumar and Oommen, 2011). However, lower relative dominance of Euglenophyceae with respect to total species at the study sites point at negligible to lesser degree of organic pollution. The distribution of phytoplankton is dependent upon their ecological amplitude as well as prey predator relationship existing in the aquatic system. It was demonstrated in a study that the phytoplankton biomass was significantly correlated with the zooplankton biomass (McCauley and Kalff, 1981). It is still an interesting study to know if increase or decrease in the grazing pressure on phytoplankton by zooplankton and other fauna has a notable effect on the phytoplankton diversity/density or not.

The species composition varied depending upon affinity of various phytoplankton species to the existing ecological conditions. To check the similarities among the reservoirs with respect to presence/absence data was used and 'Sorenson's coefficient' was calculated. The similarity in phytoplankton species composition with Dhanora and Vadadala were 72 % and 71% respectively, whereas the similarity between Vadadala and Dhanora was merely 56 % (Figure 6.28). Nearly 35 % of dissimilarity in the phytoplankton community between these two reservoirs can be a function of varied nutrient availability and other environmental factors.

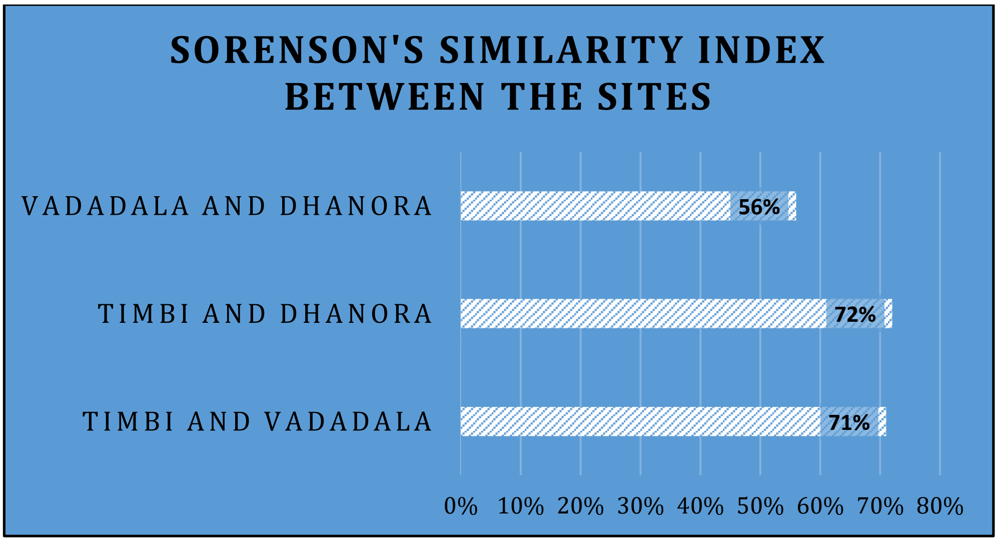

Figure 6.28 Sorenson's Similarity Index between the sites with reference to phytoplankton diversity

It is evident that the diversity and density of phytoplankton is largely governed by the nutrient inputs even when other parameters are almost similar. In this study, the post hoc analysis of reservoirs indicate that the mean difference of Vadadala with Timbi and

Dhanora attributed to Nitrate and Phosphate Concentration is significant (Table 6.4); which means that Nitrate and Phosphate concentrations in Vadadala are significantly non similar in comparison to Timbi and Dhanora. Moreover, the same test also indicated that with respect to Nitrate and Phosphate concentration, Timbi and Dhanora are quite similar. Such similar condition of nutrients attributes to greater similarity between the two reservoirs with respect to phytoplankton species. The same condition also explains the dissimilarity between Vadadala and Dhanora reservoirs, however, the similarity between the Timbi and Vadadala reservoirs needs further investigation for explanation.

6.4 AVIFAUNAL DIVERSITY IN AND AROUND WETLAND

The influence of abiotic factors and benthos community were studied in the previous attempts for a number of reservoirs, and such parameters showed a notable influence on the wetland bird diversity (Patel, 2013). In view of the same, assessment of avifaunal diversity was considered as one of the components of investigation.

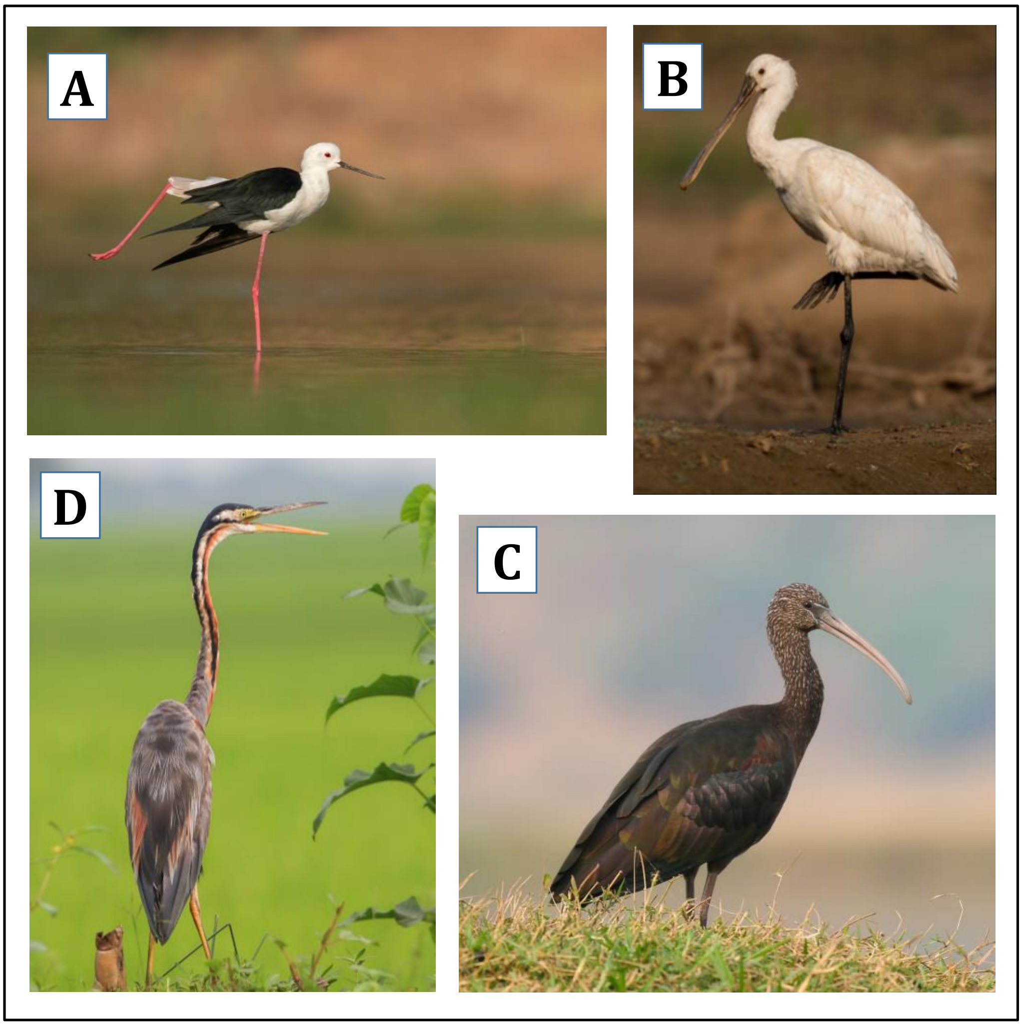

Figure 6.29 Wetland Birds at different study sites

A: Black – winged stilt (*Himantopus himantopus*), B: Eurasian spoonbill (*Platalea leucorodia*), C: Purple heron (*Ardea purpurea*), D: Glossy ibis (*Plegadis falsinellus*) (Image Curtsey: Mr. Shubham Akolkar)

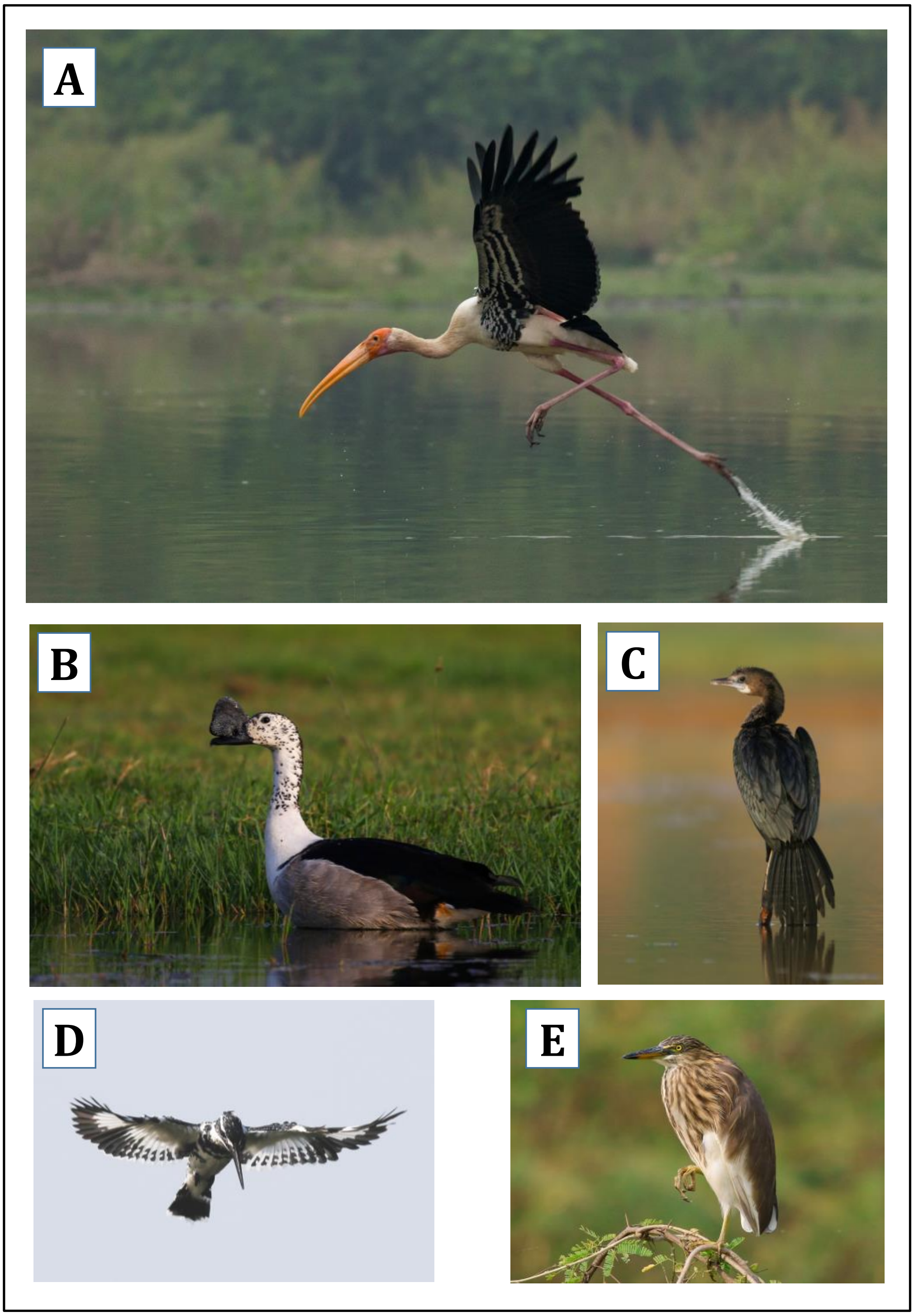

Figure 6.30 Wetland Birds at different study sites;

A: Painted stork (*Mycteria leucocephala*), B: Knob billed duck (*Sarkidiornis melanotos*), C: Little cormorant (*Microcarbo niger*), D: Pied kingfisher (*Ceryle rudis*), E: Indian pond heron (*Ardeola grayii)* (Image Curtsey: Mr. Shubham Akolkar)

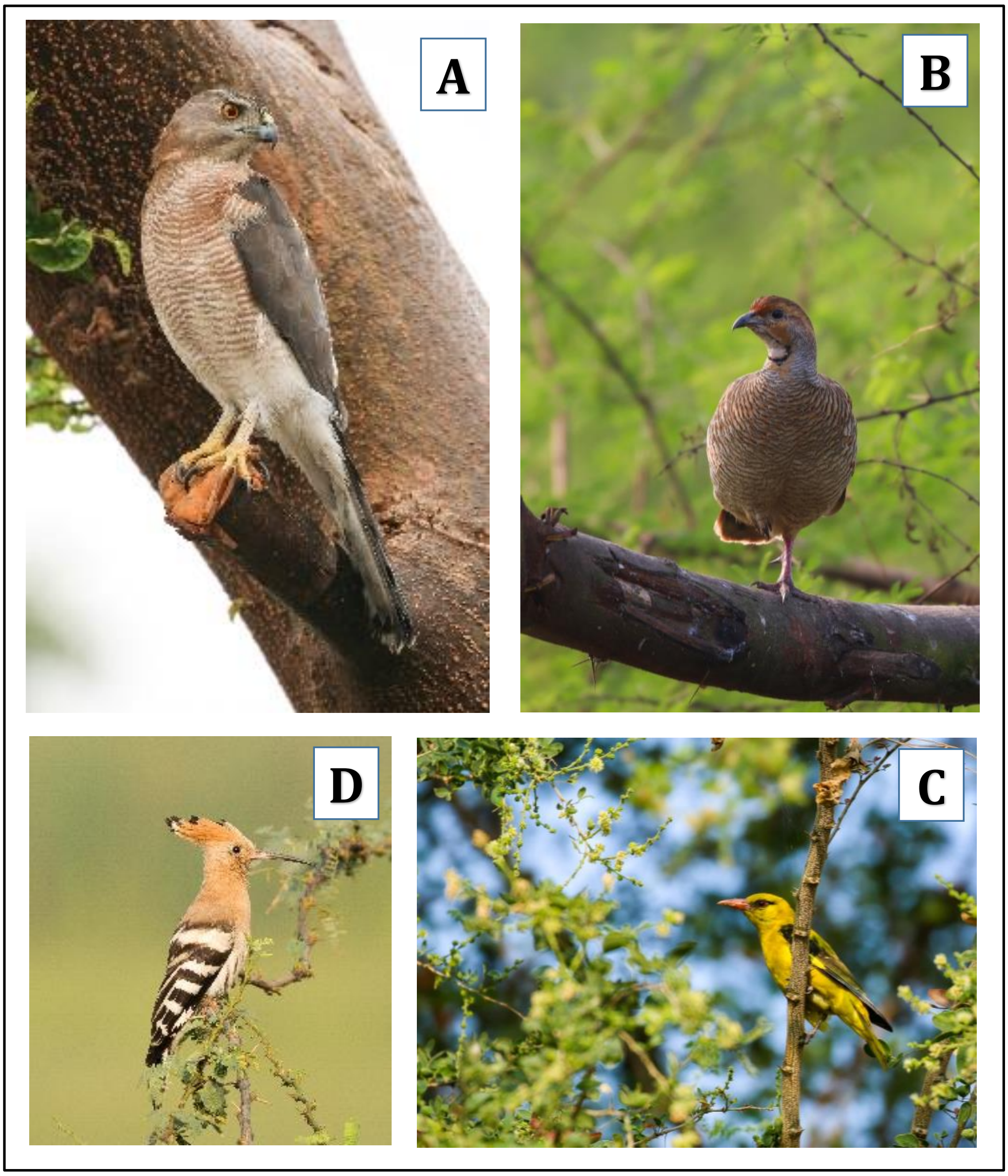

Figure 6.31 Non wetland birds at different study sites:
A: Shikra (*Accipiter badius*), B: Grey francolin (*Fracnolinus pintadeanus)*, C: Indian golden oriole (*Oriolus kundoo*), D: Common Hoopoe (*Upupa epops*) (Image Curtsey: Mr. Shubham Akolkar)

During the current study, a total of 71 bird species belonging to 39 different families were recorded (Annexure III). Out of these, 64, 47 and 42 species were recorded at Timbi, Dhanora and Vadadala reservoirs respectively. Some of the indicative birds are shown in Figure 6.29, 6.30 and 6.31.

The study included enlisting of both the wetland birds and non-wetland birds. Non-wetland birds were the ones which were present in area surrounding the reservoirs. These areas include trees, bushes, grasses as well as agricultural field. Out of the 71 bird species, 36 were wetland birds 35 were non-wetland birds.

It would not be logical to compare the reservoirs with respect to all the birds, thus Sorenson's Similarity Index was calculated for all the sites considering only the wetland birds.

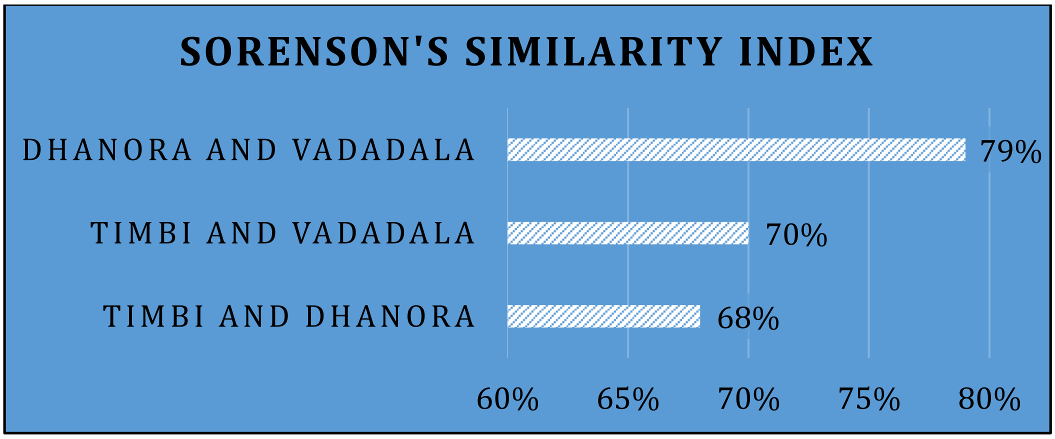

Figure 6.32 Sorenson's Similarity Index between the sites

The Sorenson's Similarity Index (expressed as percentage value of the fraction) indicate maximum similarity between Dhanora and Vadadala Reservoirs (Figure 6.32). It is noteworthy that the maximum number of wetland birds were present at Timbi reservoir viz., 64; indicating most favourable condition for the wetland avifauna. Previous studies indicate that the anthropogenic activity and land use in surrounding areas are known to be influential to the wetland bird diversity (DeLuca *et al*., 2004). Considering the phytoplankton diversity, all the three reservoirs had reasonable similarity. However, the correlation coefficient between the temperature and Nitrate in case of Timbi reservoir indicate a negative relationship. This suggests that during the winters (where the temperatures are low) the nitrate is bound in the biomass rather than in the water as a dissolved nutrient. This indirectly indicate higher food resources availability in Timbi reservoir in comparison to the other two. In spite of this indirect indication, there needs further investigation of the food web and biomass accumulation at each trophic level to precisely justify the higher wetland bird diversity at Timbi and relatively lesser diversity at Dhanora and Vadadala reservoirs.

In addition to the above, the wetland birds also depend upon other wetland birds and wetland vegetation. They often select a site and generally become repeated visitors of the same site unless there is drastic change in the character of the habitat (Ward *et al*., 2010). Here, the sites under investigation had relatively similar type of land use and anthropogenic activities in the vicinity of the reservoirs. Considering the food resources, with respect to phytoplankton diversity, all the three reservoirs had notable similarity, except between Dhanora and Vadadala. Since last five (05) years there has not been any drastic change in the habitat at Timbi and thus, the wetland birds might not have needed to shift elsewhere. This could be one of the possible reason of clustered distribution of wetland birds in the study area. Out of all the three study sites, Timbi reservoir was having the highest diversity of wetland and non-wetland birds.