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Monitoring Seasonal Dynamics of Physicochemical Water Quality of Chhari Dhandh Wetland, Gujarat (India)

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***Abstract*—** Water quality monitoring of Chhari Dhandh natural wetland in western Kachchh, Gujarat was carried out on seasonal basis for the years 2019-20 (most recent year) and 2018-19 (previous year) with an aim of understanding extent of dynamicity of water quality. The water samples were collected from the surface of the wetland from two predominant habitats of the wetland (i.e., Open Water and Marshy Emergent Vegetation). Ten water quality parameters, i.e., pH, water temperature, dissolved oxygen, turbidity, electrical conductivity, alkalinity, total hardness, chlorides, salinity and phosphates were seasonally monitored during the study. The collection, sampling and analysis were done according to Standard methods. The study has revealed that irrespective of the seasons, the surface water of the wetland remained alkaline throughout the study tenure. However, there was a noticeable variation in some parameters like water temperature, turbidity, Electrical Conductivity (EC), Total Hardness (TH), chlorides, salinity and phosphates. Comparison of values of certain parameters against values of the Bureau of Indian Standards as well as World Health Organization values for the respective parameters has indicated that though the wetland's water is not potable, but it is appropriate for livelihood, agriculture and fishing.

Keywords— Chhari Dhandh, Physicochemical parameters. Seasonal. Variation. Water quality. Wetland

I. INTRODUCTION

Wetlands deliver a range of ecological services such as water purification [1], groundwater recharge [2] and also provide habitats to wildlife [3]. Wetland ecology is directly connected to the extent and duration of wetland inundation and the quality of water [4]. Seasonal and annual rainfall patterns exert predominant influence on wetland water levels. Seasonal wetlands receive water from flowing rivers, directly from precipitation, surface water run-off, interflow (i.e., water flowing through the soil profile), groundwater (including deep and/or perched groundwater) or any combination of these [5,6]. Water levels in isolated, lacustrine, and riverine wetlands fluctuate in response to the annual and seasonal variations in rainfall and evapotranspiration.

Chhari Dhandh is one such example of a natural, shallow water seasonal lacustrine wetland. It is the only Conservation Reserve in Gujarat state. It is also an Important Bird and Biodiversity Area (IBA) site in Gujarat. As per SACON's inland wetland prioritization [7], It is also considered as a wetland having a potential of getting recognition as Ramsar Site. Gujarat Ecological Education and Research (GEER) Foundation has been monitoring water quality of Chhari Dhandh since 2016 under a scheme assigned by Forests and Environment Department, Gujarat State. Water quality dynamics were monitored seasonally from the water samples collected from eight selected sampling sites. The present research paper is based on GEER Foundation's monitoring activity that was carried out from March 2018 to April 2020.

Section I gives the Introduction about the topic; Section II contains the related work done by other researchers on wetlands, Section III contains the study area as well as the methodology followed, Section IV elaborates the results and discussion and Section V concludes the research work

II. RELATED WORK

Wetlands have gained attention worldwide; significant research is being carried out on wetlands in various countries of the world. Numerous researchers have worked on wetlands of India and Gujarat. S. Rameshkumar et al. (2019) studied the physico-chemical characteristics of water parameters and its influences of aquatic macrophytes in seasonal wetland ecosystem in the southeast coast of India [8]. Nirmal Kumar and Cini Oommen explored the variations in hydrochemical characters of two significant wetlands of central Gujarat named Khodiar and Malwar [9]. The present monitoring has the potential to give early indication to the management if some undesirable change might be taking place and in turn, the managers can take mitigation measures.

III. METHODOLOGY

Study Area

Chhari Dhandh (23°34' 42.54″ N latitudes, 69°18' 58.08″E longitudes) is located in western Kachchh, 80 km south-

west of Bhuj and about 25 km north of Nakhtrana town in Kachchh district (Figure 1). It is situated in "Nani Banni" area and near the southern fringe of Great Rann of Kachchh. Fulay is the nearest village that is well-connected to Nakhatrana by road. Chhari Dhandh receives water mainly from precipitation. Its major habitat components are open water and marshy emergent vegetation cover. The present study assessed the seasonal variation of water quality for the two successive years from March 2018 to April 2020 (i.e., 2018-19 and 2019-20) of the seasonal wetland.

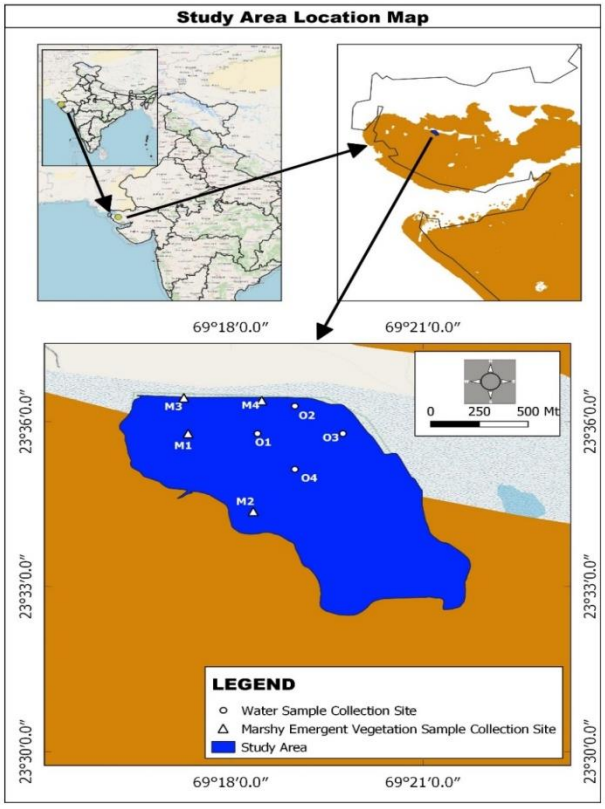

Figure 1: Location of the study area and wetland sampling sites from Chhari Dhandh wetland, Gujarat (India)

Physicochemical Parameters Analysis

To monitor the physicochemical water quality during different seasons (winter, summer, monsoon) in the most recent year (2019-20) and its previous year (2018-19), the surface water samples were collected from the selected eight sites representing two major predominant habitats (Open Water & Marshy Emergent Vegetation) of Chhari Dhandh. These included 4 water sampling sites [O1, O2, O3 & O4] in Open Water habitat and other 4 water sampling sites [M1, M2, M3 & M4] in Emergent Marshy Vegetation. The seasonal variation monitoring in the values of physicochemical parameters of the Chhari Dhandh's surface water for the two successive years (i.e., 2019-20 and 2018-19) was very useful. This is because both the years were characterized by different hydrological and habitat conditions. During the year (2018-19) water was present in the wetland only during the summer season. After that, as there was no rainfall in the region, this seasonal wetland and the whole surrounding region remained completely dry as there was no precipitation during the year 2018-19. In other words, the wetland and its surrounding landscape remained dry during monsoon and winter seasons of 2018-19. During the year (2019-20) water was present in the wetland during monsoon and winter though in summer the wetland area had dried up completely (Figure 2). The water samples were collected by grab sampling approach and unstable parameters like pH, water temperature, turbidity, dissolved oxygen (DO), electrical conductivity were analyzed at the sites itself. Water samples were collected in 1 litre polyethylene bottles, neatly labelled and stored in ice boxes and transported to the GEER Foundation's laboratory for further analysis of the remaining parameters like alkalinity, chlorides, salinity, total hardness and phosphates [10].

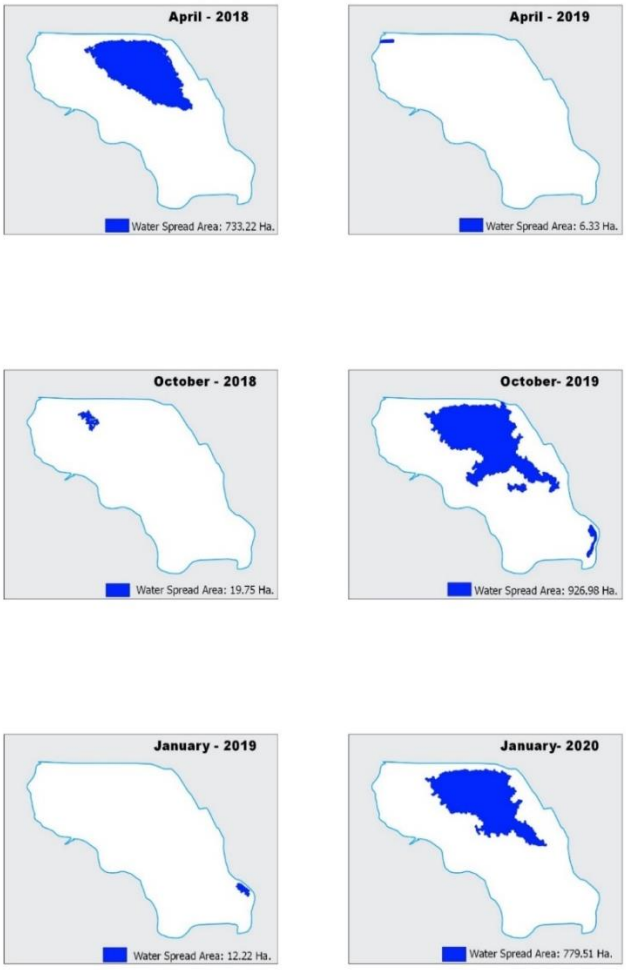

Figure 2: Water level/spread scenario in Chhari dhandh wetland during different seasons of 2018-19 and 2019-20 (**Summer**-March-June; **Monsoon** -July-September; **Winter** - November-February)

IV. RESULTS AND DISCUSSION

The present study was conducted at eight selected sampling sites (4 in Open Water-O1 O2, O3, O4 and other 4 in Marshy Emergent Vegetation-M1, M2, M3, M4) of Chhari Dhandh. The seasonal variations of physicochemical parameters at all the eight sampling sites are shown in Figure 3 to Figure 22.

pH

pH is an important characteristic of any aquatic ecosystem as all the biochemical functions and the physicochemical features of water are dependent on pH of the neighboring environments [11]. Most of the aquatic organisms are very sensitive to pH change [12]. During the most recent year of ecological monitoring of Chhari Dhandh (i.e., 2019-20), pH of Chhari Dhandh's water varied from 7.10 to 8.04 in the monsoon season and from 7.01 to 7.90 in the winter season (Figure 3). On the other hand, during the previous year (2018-19), the pH values of Chhari Dhandh's water samples ranged from 7.60 to 8.45 in the summer season (Figure 4). Considering both the years (2018-19 & 2019-20), the highest value of pH (8.45) was recorded in summer season during the previous year (2018-19) and it was recorded at **M1** representing Emergent Marshy Vegetation area. Elevated value of pH recorded in summer season might be due to photosynthetic activities that demand more carbon dioxide than quantities furnished by respiration and decomposition [13]. According to [14] high pH values promote the growth of phytoplankton and result in blooms. As many waterbirds, especially flamingos and some anatids feed on phytoplankton, high (i.e. alkaline) pH may be beneficial to such waterbirds occurring at Chhari Dhandh. On the other hand, the lowest value of pH (7.01) was recorded at **O1** representing Open Water and **M1** representing Emergent Marshy Vegetation in the monsoon season of the most recent year (2019-20). Low value of pH recorded during monsoon season might be attributed to the rainfall leading to the dilution of the wetland's water. A decline in the pH value during monsoon season was also recorded by [15].

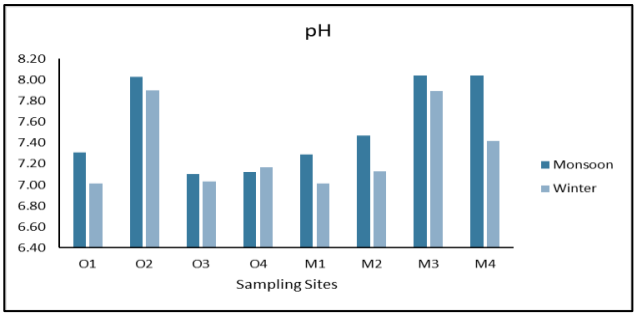

Figure 3: pH variation in two predominant habitats (Open Water & Marshy Emergent Vegetation) of Chhari Dhandh in monsoon and winter seasons of most recent year (2019-20)

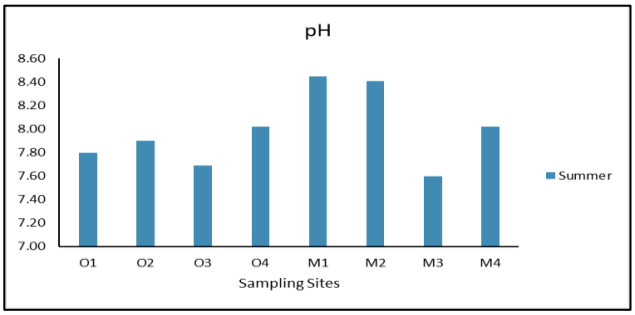

Figure 4: pH variation in two predominant habitats (Open Water & Marshy Emergent Vegetation) of Chhari Dhandh during summer in the previous year (2018-19)

Water Temperature

Water temperature variations are mostly governed by the climatic conditions. Precipitation and solar radiations are the major climatic conditions that influence most of the physicochemical parameters of wetlands [16,17]. The variations in the temperature of the water might be due to the difference between the water sample collection time, influence of the season etc. Water temperature is known to influence the life of aquatic organisms. Increasing temperature positively influences the growth and survival of aquatic organisms [18]. Increase and decrease in water temperature is attributed to the increase and decrease in solar radiation due to changes in day length [19-21]. During the most recent year (2019-20) of ecological monitoring of Chhari Dhandh, water temperature varied from 21.04 °C to 24.04 °C in the monsoon season and from 21.08 °C to 25.08°C in the winter season (Figure 5). On the other hand, during the previous year (2018-19) of monitoring, water temperature varied in the summer season from 23.02 °C to 29.80 °C (Figure 6). Considering both the years (2018-19 & 2019-20), the highest value of Water Temperature (29.8 °C) was recorded in the summer season during the previous year (2018-19) at **M1** representing Marshy Emergent Vegetation area. On the other hand, the lowest value of Water Temperature (21.4 °C) was recorded during the monsoon season of the most recent year (2019-20) at **O4** representing Open Water area and at **M4** representing Marshy Emergent Vegetation area. Generally, water temperature of shallow water areas has direct relevance with air temperature as mentioned by [22] as water of shallow zone reacts quickly to changes in atmospheric temperature.

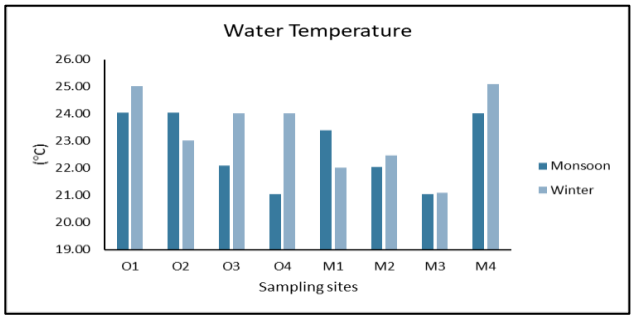

Figure 5: Water temperature variation in two predominant habitats (Open Water & Marshy Emergent Vegetation) of Chhari Dhandh in monsoon and winter seasons of the most recent year (2019-20)

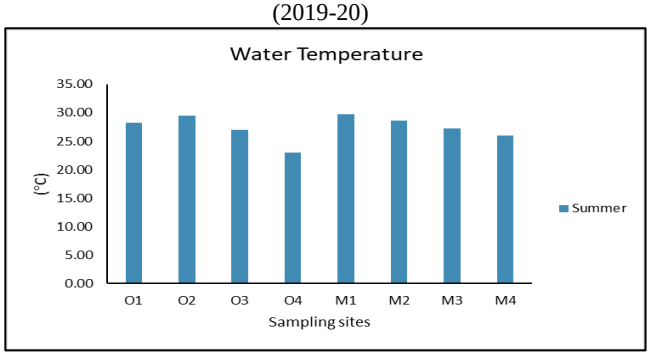

Figure 6: Water Temperature variations in two predominant habitats (Open Water & Emergent Marshy Vegetation) of Chhari Dhandh in summer during the previous year (2018-19)

Turbidity

Clay, slit, organic matter, phytoplankton and other microscopic organisms cause turbidity in lake water. High turbidity indicates presence of large quantity of suspended solids [10]. During the most recent year (2019-20) of ecological monitoring of Chhari Dhandh, turbidity varied from 28.01 NTU to 312 NTU in the monsoon season and from 40.80 NTU to 131.04 NTU in the winter season (Figure 7). However, during the previous year (2018-19) of monitoring, the surface water Turbidity ranged from 147.0 NTU to 245.0 NTU in the summer season (Figure 8). Considering both the years (2018-19 & 2019-20), the highest value of Turbidity (312 NTU) was recorded in the monsoon season during the most recent year (2019-20) at **O3** representing open water area. High value of Turbidity in monsoon season suggested presence of high concentration of suspended solids [23]. Rainwater run-off is known to bring considerable amount of suspended solids into the wetlands. High values of turbidity affect the aquatic life as it cuts off light that is used by the submerged vegetation for photosynthesis thereby reducing the rate of primary productivity [24,25]. On the other hand, the lowest value of Turbidity (28.01 NTU) was recorded in the monsoon season during the most recent year (2019-20) at **O1** representing Open Water area. Such low values of turbidity might be attributed to the dilution of water resulting from precipitation and comparatively low run off from the wetland.

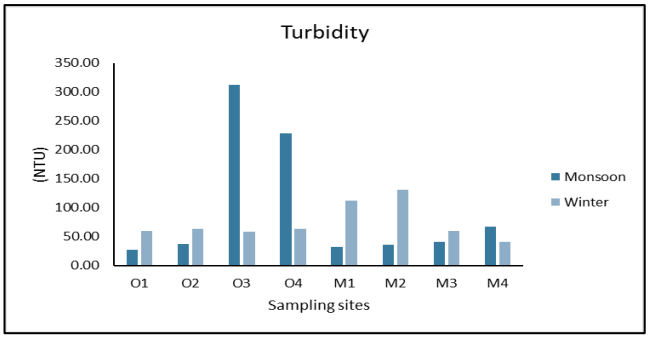

Figure 7**:** Turbidity variation in two predominant habitats (Open Water and Marshy Emergent Vegetation) of Chhari Dhandh in monsoon and winter seasons of most recent year (2019-20)

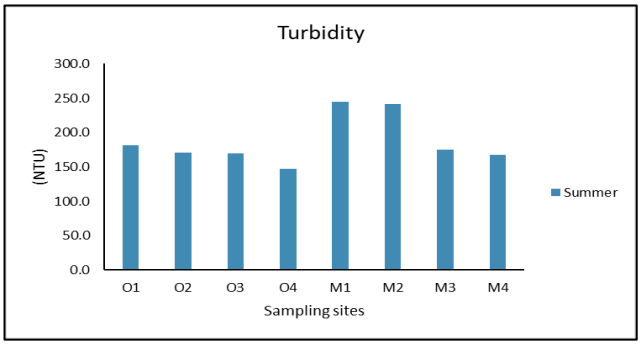

Figure 8: Turbidity variation in two predominant habitats (Open Water and Marshy Emergent Vegetation) of Chhari Dhandh in summer of the previous year (2018-19)

Dissolved Oxygen (DO)

Dissolved Oxygen (DO) refers to the amount of oxygen present in wetland and indicates the health of the ecosystem. DO highly depends upon temperature and salinity of water. The DO level indicates the degree of pollution in the aquatic ecosystem [26]. The aquatic life gets stressed when DO levels drop to 4-2 mg/lit. [27] that might lead to undesirable changes in odor, taste and color and reduce the usefulness of water [28]. DO levels ranging from 5 mg/l to 8 mg/l are satisfactory for the survival and growth of aquatic organisms. During the most recent year (2019-20) of ecological monitoring of Chhari Dhandh, DO varied from 5.06 mg/l to 6.10 mg/l in the monsoon season and from 5.01 mg/l to 7.09 mg/l in the winter season (Figure 9). However, during the previous year (2018-19), of monitoring, DO of the surface water OF Chhari Dhandh ranged from 5.18 mg/l to 6.90 mg/l in the summer season (Figure 10). Considering both the years (2018-19 & 2019-20), the highest value of DO (7.09 mg/l) was recorded in the winter season during the most recent year (2019-20) at **M3** representing Marshy Emergent Vegetation area. High value of DO recorded in winter season might be due to the increased solubility of oxygen at lower temperature [29]. On the other hand, the lowest value of Dissolved Oxygen (5.01 mg/l) was recorded in the winter season during the most recent year (2019-20) at **O1** (Open Water). The low value of DO might be due to higher atmospheric temperature that ultimately elevates the water temperature leading to depletion of Dissolved Oxygen due to reduction in water density causing DO release from water. Depletion of Dissolved Oxygen in aquatic ecosystems is due to high temperature and increased microbial activity [30].

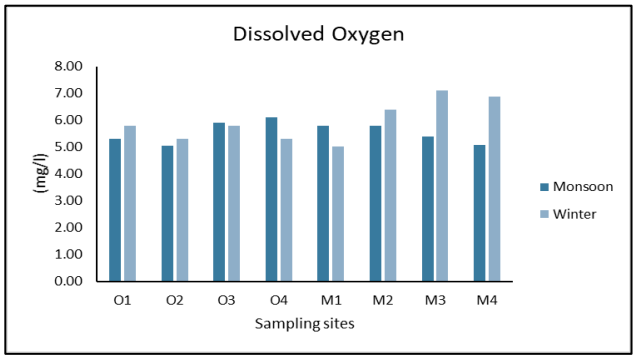

Figure 9: Dissolved Oxygen (DO) variation in two predominant habitats (Open Water & Marshy Emergent Vegetation) of Chhari Dhandh in monsoon and winter seasons of most recent year (2019-20)

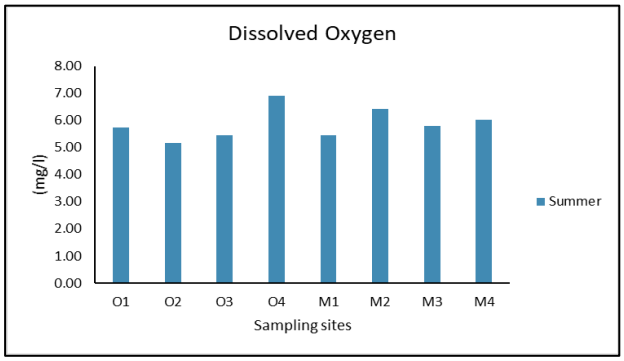

Figure 10: Dissolved Oxygen variation in two predominant habitats (Open Water and Marshy Emergent Vegetation) of Chhari Dhandh in summer during previous year (2018-19)

Electrical Conductivity

Conductivity of water depends upon the concentration of ions and status of nutrients and variation in dissolved solids content in water. Seasonal variation in the conductivity is mostly due to increased concentration of salts as a result of evaporation. During the most recent year (2019-20) of ecological monitoring of Chhari Dhandh, Electrical conductivity varied from 14.03 mS to 21.04 mS in the monsoon season and from 1.47 mS to 4.99 mS in the winter season (Figure 11). During the most recent year (2019-20) of ecological monitoring of Chhari Dhandh, Electrical conductivity varied from 11.46 mS to 15.01 mS in the summer season (Figure 12). Considering both the years (2018-19 & 2019-20), the highest value of Electrical conductivity (21.04 mS) was recorded in the monsoon season of the most recent year (2019-20) at **M4** representing Marshy Emergent Vegetation. High value of electrical conductivity during monsoon season indicates addition of some pollutants through rainwater run-off draining into the wetland [31]. On the other hand, the lowest value of Electrical Conductivity (1.47 mS) was recorded in the winter season of the most recent year (2019-20) at O1 (Open Water). Similar results were recorded by various researchers [32,33].

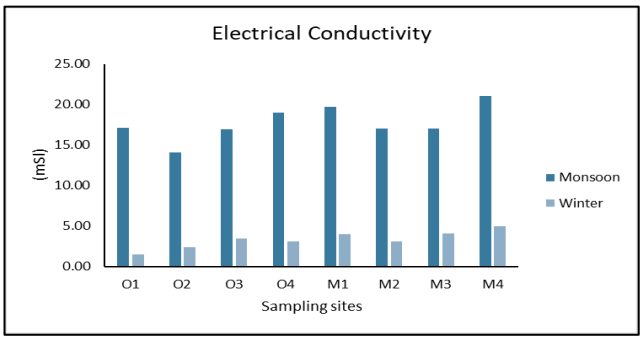

Figure 11: Electrical Conductivity (EC) variation in two predominant habitats (Open Water & Marshy Emergent Vegetation) of Chhari Dhandh in monsoon and winter seasons of most recent year (2019-20)

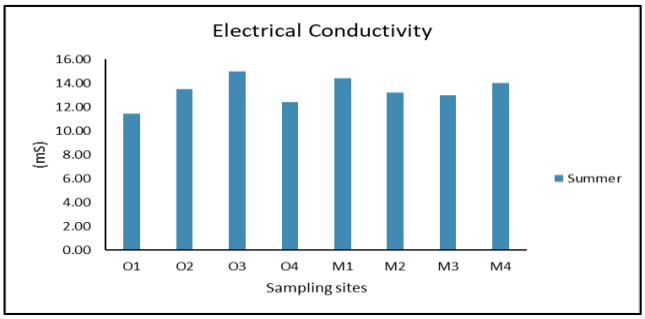

Figure 12: Electrical Conductivity (EC) variation in two predominant habitats (Open Water and Marshy Emergent Vegetation) of Chhari Dhandh in summer during previous year (2018-19)

Alkalinity

Measuring total alkalinity is significant as it is dependent on the concentration of the substance which would raise the pH of water. Wetland waters are rich in hydroxide, carbonate and bicarbonate ions that impart alkalinity [34]. During the most recent year of ecological monitoring of Chhari Dhandh (i.e. 2019-20), Alkalinity of Chhari Dhandh's water varied from 151.8mg/l as $CaCO_3$ to 240.35 mg/l as $CaCO_3$ in the monsoon season and from 134.3 mg/l as $CaCO_3$ to 196.9 mg/l as $CaCO_3$ in the winter season (Figure 13). On the other hand, during the previous year (2018-19), the Alkalinity of the surface water ranged from 30 mg/l as $CaCO_3$ to 60 mg/l as $CaCO_3$ in the summer season (Figure 14). Considering both the years (2018-19 & 2019-20), the highest value of Alkalinity (240.35 mg/l as $CaCO_3$) was recorded in the monsoon season during the most recent year (2019-20) at **O1** representing open water area. High value of alkalinity during the monsoon season might be attributed to runoff from the nearby surrounding areas. Additional increase during post-monsoon is facilitated by faster degradation of plants, living organism and organic waste might also lead in the increase in a carbonate and bicarbonate, resulting an increase in alkalinity value [35]. On the other hand, the lowest value of Alkalinity (30 mg/l as $CaCO_3$) was recorded in the summer season during the previous year (2018-19) at **O1** representing open water area & at **M1** representing Emergent Marshy Vegetation area.

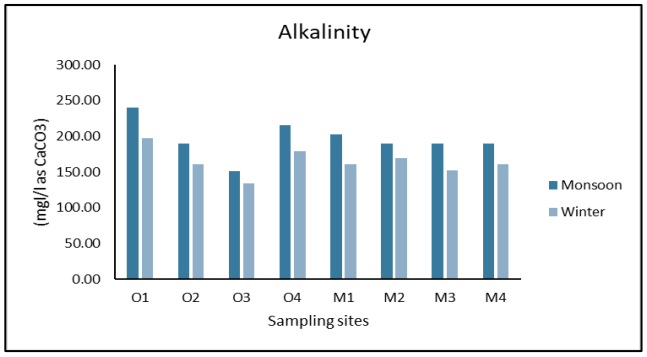

Figure 13: Alkalinity variation in two predominant habitats (Open Water & Marshy Emergent Vegetation) of Chhari Dhandh in monsoon and winter seasons of most recent year (2019-20)

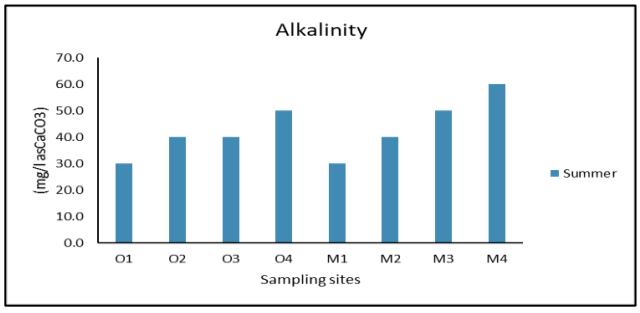

Figure 14: Alkalinity variation in two predominant habitats (Open Water and Marshy Emergent Vegetation) of Chhari Dhandh in summer during previous year (2018-19)

Chlorides

Chlorides play an important role in water quality determination [36]. Dissolution of salt or agriculture runoffs and non-point pollution sources are responsible for the increased concentrations of chlorides in natural waters [37]. The chloride concentration is one of the important indicators of water pollution [38,39]. During the most recent year of ecological monitoring of Chhari Dhandh (i.e.

2019-20), chlorides of Chhari Dhandh's water varied from 4.48 ppt to 4.88 ppt in the monsoon season and from 0.99 ppt to 2.24 ppt during the winter season (Figure 15). On the other hand, during the previous year (2018-19), the chlorides of the surface water ranged from 4.4 to 5.1 ppt during the summer season (Figure 16). Considering both the years (2018-19 & 2019-20), the highest value of chlorides (5.1 ppt) was recorded at **M2** representing marshy emergent vegetation area in the summer season during the previous year (2018-19). High value of chlorides during summer season might be due to the rise in temperature and evaporate transpiration, which could be explained by the fact that the presence of chloride salts may interfere with other nutrients, which are being utilized in the process of photosynthesis. High chlorides indicate good salt concentration in waters. High chlorides indicate good salt concentration in waters. Lesser Flamingos using open water areas of this wetland for feeding on diatoms and blue-green algae are partial to such waters. Similar observations were recorded by many researchers like [40-42]. On the other hand, the lowest value of chlorides (0.99 ppt) was recorded at **M1** representing marshy emergent vegetation area in the winter season during the most recent year (2019-20). [43] recorded higher values of chlorides during summer season and lower during winter season in Harsool Savangi water body.

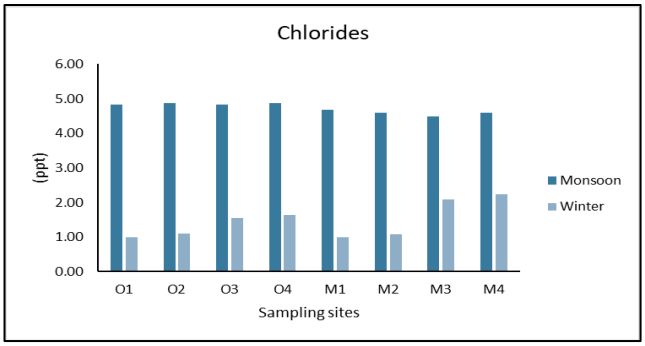

Figure 15: Chlorides variation in two predominant habitats (Open Water & Marshy Emergent Vegetation) of Chhari Dhandh in monsoon and winter seasons of most recent year (2019-20)

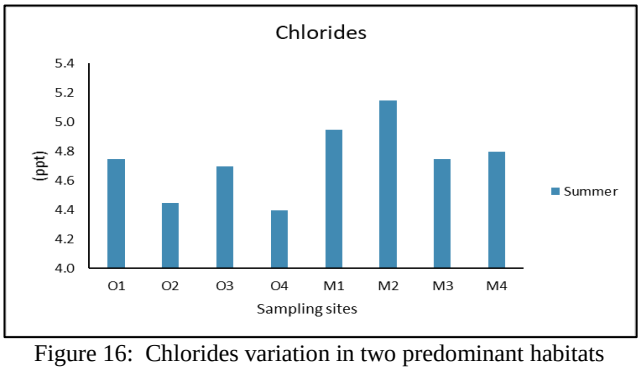

Figure 16: Chlorides variation in two predominant habitats (Open Water and Marshy Emergent Vegetation) of Chhari Dhandh in summer during previous year (2018-19)

Salinity

Salinity is a direct measure of the amount of salts in the water. A minor change in salinity may influence other physical, chemical and biological parameters [44,45]. During the most recent year of ecological monitoring of Chhari Dhandh (i.e. 2019-20), salinity of Chhari Dhandh's water varied from 4.0 ppt to 9.8 ppt during the monsoon season and from 2.0 ppt to 3.09 ppt during the winter season (Figure 17). On the other hand, during the previous year (2018-19), the salinity of the surface water ranged from 7.3 ppt to 8.5 ppt during summer season (Figure 18). Considering both the years (2018-19 & 2019-20), the highest value of salinity (9.8 ppt) was recorded at **O4** represented by Open Water area in the monsoon season during the most recent year (2019-20). High salinity during the monsoon season might be ascribed to low rainfall, decreased fresh water inflow, high temperature and evaporation [46-48]. It may be noted that Lesser Flamingos that regularly occur at Chhari Dhandh are known to prefer brackish to saline waters for feeding on diatoms and blue-green algae. On the other hand, the lowest value of salinity (2.0 ppt) was recorded at **M1** representing marshy emergent vegetation area in the winter season during the most recent year (2019-20).

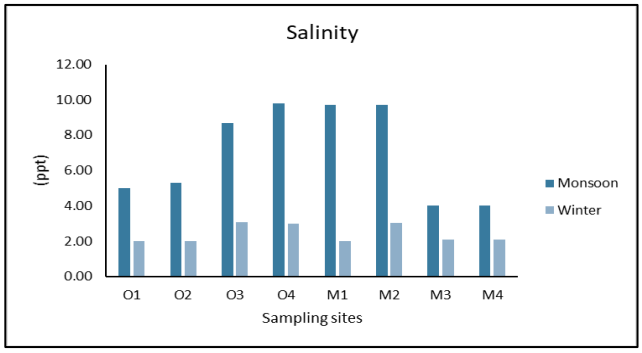

Figure 17: Salinity variation in two predominant habitats (Open Water & Marshy Emergent Vegetation) of Chhari Dhandh in monsoon and winter seasons of most recent year (2019-20)

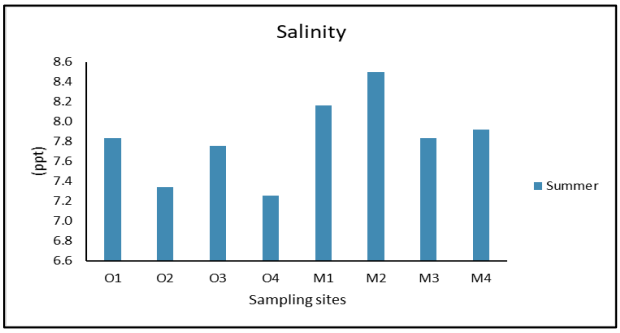

Figure 18: Salinity variation in two predominant habitats (Open Water and Marshy Emergent Vegetation) of Chhari Dhandh in summer during previous year (2018-19)

Total Hardness

[49] classified wetlands on the basis of hardness into three categories, viz., soft, moderately hard and hard. During the most recent year of ecological monitoring of Chhari Dhandh (i.e. 2019-20), total hardness of Chhari Dhandh's water varied from 180.0 mg/l as $CaCO_3$ to 300 mg/l as $CaCO_3$ in the monsoon season and from 530.0 mg/l as $CaCO_3$ to 610.0 mg/l as $CaCO_3$ in the winter season (Figure 19). On the other hand, during the previous year (2018-19), the total hardness values of Chhari Dhandh's water

samples ranged from 1700 mg/l as $CaCO_3$ to 2600 mg/l as $CaCO_3$ in the summer season (Figure 20). Considering both the years (2018-19 & 2019-20), the highest value of Total Hardness (2600 mg/l as $CaCO_3$) was recorded in the summer season during the previous year (2018-19) at **O3** represented by open water area. High value of total hardness recorded in summer season might be due to the higher temperatures resulting the decline in the water level leading to excessive evaporation which increases the concentrations of salts. On the other hand, the lowest value of Total Hardness (180.0 mg/l as $CaCO_3$) was recorded in the monsoon season during the most recent year (2019-20) at **M4** representing Marshy Emergent Vegetation area.

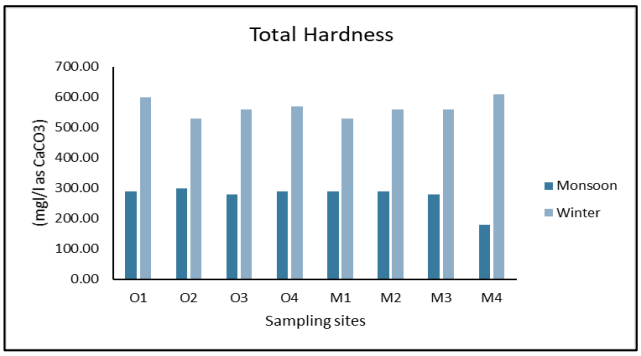

Figure 19: Total Hardness variation in two predominant habitats (Open Water & Marshy Emergent Vegetation) of Chhari Dhandh in monsoon and winter seasons of most recent year (2019-20)

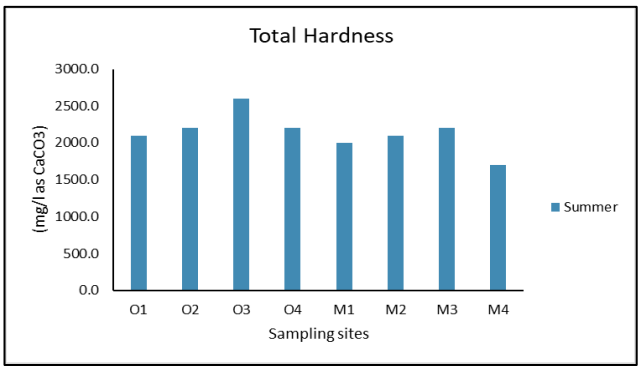

Figure 20: Total Hardness variation in two predominant habitats (Open Water and Marshy Emergent Vegetation) of Chhari Dhandh in summer during previous year (2018-19)

Phosphates

Phosphates are generally recognized as one of the key nutrients in the productivity of freshwaters as it is an essential element determining the fertility of lakes [50]. It is one of the major limiting nutrients that triggers eutrophication of freshwater systems [51]. During the most recent year of ecological monitoring of Chhari Dhandh (i.e. 2019-20), phosphates of Chhari Dhandh's water varied from 0.94 mg/l to 2.04 mg/l in the monsoon season and from 0.33 mg/l to 13.70 mg/l in the winter season (Figure 21). On the other hand, during the previous year (2018-19), the phosphate values of Chhari Dhandh's water samples ranged from 0 to 2 mg/l during the summer season (Figure 22). Considering both the years (2018-19 & 2019-20), the highest value of phosphates (13.7 mg/l) was recorded in winter season during the most recent year (2019-20) at **O1** representing open water area. On the other hand, the lowest value of phosphates (0.1 mg/l) was recorded in the summer season during the previous year (2018-19) at **O4** representing open water area & **M4** representing marshy emergent vegetation area. Low value of phosphates in summer season might be due to more uptake of phosphate for luxuriant growth of macrophytes [52].

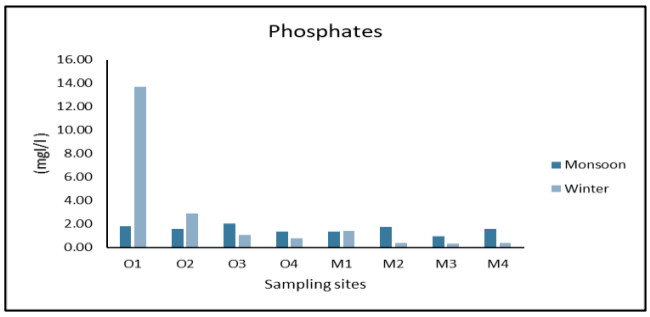

Figure 21: Phosphates variation in two predominant habitats (Open Water & Marshy Emergent Vegetation) of Chhari Dhandh in monsoon and winter seasons of most recent year (2019-20)

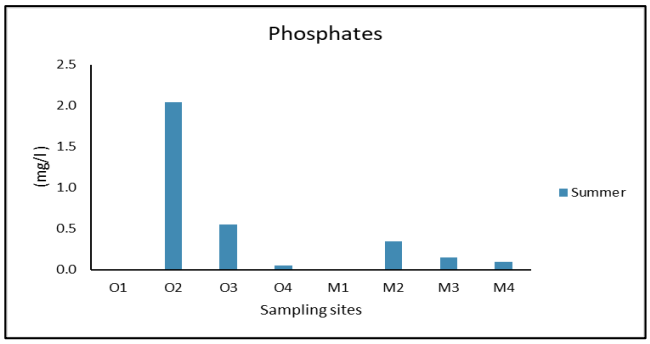

Figure 22: Phosphates variation in two predominant habitats (Open Water and Marshy Emergent Vegetation) of Chhari Dhandh in summer during previous year (2018-19)

V. CONCLUSION

This study has revealed that the physical and chemical characteristics of surface water did not follow any definite seasonal trend. It is known that as the season changes there is a fluctuation in the physicochemical characters of a wetland's surface water. At Chhari Dhandh also, such fluctuation has been recorded during the present study. The wetland was found to be in overall healthy state owing to reasonably good DO level and moderate turbidity level. Both these factors are beneficial to fish and other aquatic biota of the wetland. Salinity has also remained in fresh water to brackish water range. Nutrient status, as reflected from Phosphate concentration has indicated that the wetland is not excessively eutrophic. All these factors suggest that richness of waterbird profile of Chhari Dhandh might be due to favourable status of these water quality parameters. Care should be taken to maintain such desirable status of these parameters on long term basis by the regulatory/managing authorities of Chhari Dhandh Conservation.

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