Sustainable Urban Wetland Management in Dhaka: Role, Status and Challenges Concerning Selected Urban Water Bodies

Doctor of Philosophy (PhD) Dissertation

By

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Certificate of the Supervisor

The thesis entitled 'Sustainable Urban Wetland Management in Dhaka: Role, Status and Challenges Concerning Selected Urban Water Bodies' submitted by Subarna Sharmin bearing PhD registration no. 26/2022-2023 at the Department of Development Studies, University of Dhaka towards the award of a degree of Doctor of Philosophy has not been submitted for any other degree of this University or any other University and it is entirely her own work.

I recommend that the thesis be placed before the examiners for evaluation.

Professor Niaz Ahmed Khan, PhD
Supervisor

Declaration

I hereby declare that the PhD Dissertation on 'Sustainable Urban Wetland Management in Dhaka: Role, Status and Challenges Concerning Selected Urban Water Bodies' has been prepared by me. It is an original research work done by me in the field through following the advices and suggestions given by my supervisor time to time. I myself take all responsibilities for all data, comments, statements and opinions made and articulated in this dissertation. This has not been submitted in part or full for any other institution for any other degree.

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Acknowledgement

The author is very much thankful to the Almighty, who has allowed her to reach at this glorious phase.

The author likes to express her sincere gratitude to her thesis Supervisor Professor Dr. Niaz Ahmed Khan, Former Chairman, Department of Development Studies, University of Dhaka for his extraordinary sincere guidance, constant valuable suggestions, continuous encouragement and support throughout the entire research work to bring the research to this final stage. The author honestly appreciates the efforts he had paid even in late hours during study period for long time discussions and wishes to thank him for giving her opportunity to work on this constructive topic to perform her research study.

The author is very much grateful to the Professor Dr. Rashed Al Mahmud Titumir, Chairman, Department of Development Studies, University of Dhaka who encouraged her to complete this research work through his constructive ideas and suggestions.

The author expresses her sincere appreciations and thanks to the Associate Professor Dr. Shubhasish Barua for his valuable comments and guidance and appropriate directives to fulfill the requirements of the research. The author is deeply grateful to him.

The author is grateful to the Professor Dr. Kazi Maruful Islam for his valuable comments and suggestions to enrich the research work.

Special thanks to the all-other faculty members of the Department of Development Studies, University of Dhaka for their encouragement during research work.

Special thanks to the staff members, friends and well-wishers of the Department of Development Studies and entire Dhaka University who helped the author directly or indirectly to complete the research work.

The author is grateful to the study area stakeholders, institutional stakeholder experts who responded spontaneously during the field works, data collections and helped her by providing necessary information in connection with the research work.

The author is grateful to the Urban Planner of the Rajdhani Unnayan Kartripakkha (RAJUK), Sub-Divisional Engineer and Sub-Assistant Engineer of the Public Works Department (PWD), Deputy Director and Assistant Director of the Department of Environment (DoE), Executive Engineer of the Dhaka South City Corporation (DSCC), Executive Engineer of the Dhaka Water Supply and Sewerage Authority (DWASA), Senior Manager of the Bangladesh Fisheries Development Corporation (BFDC), Chairman of the Poribesh Bachao Andolon (POBA), Secretary, Members of the Union Parishad (for Ashulia), Secretary, Members of the Union Parishad (for Birulia), Water Resource Scientist of the BUET/BRAC University, Director, Hydro Geologist of the Institute of Water and Flood Management (IWFM), (BUET), Country Representative of the International Union for Conservation of Nature (IUCN) and Architect of the Vitti Thapotto Brindo for their continuous support and respected comments.

The author acknowledges sincere gratitude to the Director General of Department of Environment (DoE) Dhaka for allowing her to perform the tests of water quality in their Laboratory. The author is also grateful to the higher officials and laboratory technicians of Department of Environment (DoE), for their continuous support and cooperation during the research work.

Special thanks are expressed to the faculty members of the Department of Environment, Stamford University for providing detail guidance on the selection of water quality test parameters to the author for the research.

Special thanks are expressed to the Project Director and Assistant Engineer of the (RAJUK) for providing the secondary data and necessary information for the research.

Special thanks are expressed to the Bangladesh Bureau of Statistic (BBS) authorities to use their library for collection of information from different books, articles and journals.

Special thanks are expressed to Mr. Nur Hossain, for providing continuous support and help to the author during the entire research period in collecting field data and other information.

Special thanks are expressed to Ms. Mehzabin Rahman and Md. Ehsanul Hoque for their valuable suggestions during the research work.

Special thanks are expressed to Architect Sabikun Nahar and Architect Md. Mazharul Alam for their support during the research period.

Special thanks are expressed to Mr. Kobir for his valuable suggestions during the research work.

Finally, no words could possibly express the deepest gratitude to author's mother Mrs. Faizunnessa and father Engr. Md. Moksed Alam, younger sister Architect Afrin, brother-in-law Engr. Anis Rahman and precious nephew Aayan Rahman. The author dedicates this piece of work especially to her family members.

Subarna Sharmin

Abstract

Traditionally, urban wetlands have supported a multidimensional role in the city of Dhaka for a long time. However, due to challenges in the city, urban wetlands have become degraded and are presently unsustainable. Therefore, these urban wetlands urgently require improved management to revitalize them. The literature review of the research showed that there have been few specific studies on urban wetland management. Under these circumstances, considering all the constraints and challenges in the city, this research is an attempt to develop the 'Sustainable Urban Wetland Management in Dhaka: Role, Status and Challenges Concerning Selected Urban Water Bodies' which will further contribute to the development of the country. Thus, this research aims at the following objectives: (1) To explore the current scenario and existing role of urban wetlands in Dhaka, (2) To identify the challenges of urban wetland management and use in the city, (3) To assess the water quality parameter tests for identification of aquatic biodiversity and ecosystem conservation capabilities , (4) To identify the external factors and how these factors have influenced the variation of Dissolved Oxygen (DO) concentration across selected urban wetlands, (5) To make recommendations for sustainable conservation and management of the urban wetlands based on the overall observations of the study. In fulfilling the above objectives, an analytical framework has been developed as Urban Wetland Sustainability Framework (UWSF) Model - 1 according to the five attributes of sustainability that will provide the basis for investigating the current status, existing role and challenges of urban wetland on management and use according to the stakeholder's perceptions concerning sustainability paradigm in the study areas. This research has also enabled the development of the Urban Wetland Sustainability Framework (UWSF) Model - 2 for identifying external factors and how these factors influence the variation of average Dissolved Oxygen (DO) concentration that can contribute to the sustainability of urban wetland from the perspective of water quality. In terms of methodology, this research has been conducted utilizing both primary and secondary data from different sources. Primary data has been collected through semi-structured questionnaire surveys with thirty number samples of study area stakeholders' perceptions, semi-structured interviews with thirteen samples from different organizations and institutions for stakeholder expert's perceptions and author perceptions by personal field observation. In this regard, a five-point Likert scale has been used to collect required information from these stakeholder's perceptions as well. Further, primary data has been collected through the water quality assessment on ten parameters including Temperature, pH, DO, Biochemical Oxygen Demand

(BOD_5), Chemical Oxygen Demand (COD), Turbidity, Nitrate-Nitrogen (NO_3-N), Phosphate (PO_4), Total Dissolved Solid (TDS) and Electrical Conductivity (EC) in the Department of Environment (DoE) laboratory during the months of October, November and December 2020 to investigate the quality of water and its suitability for aquatic biodiversity conservation. Present research further investigated the external factors and how these factors are influencing the variation of average DO concentration across selected urban wetlands by author personal field observation. In this connection, six external factors have been selected as water pollution from sewerage effluent, water pollution from industrial effluent, population density, presence of surrounding shaded trees and vegetations, air pollution and existing wetland management structures. In this research, a total of seven study areas have been selected within and near to the capital city of Dhaka. These are Dhanmondi Lake, Gulshan-Baridhara Lake, Hatirjheel Lake, Ramna Lake, Diabari Bottola Lake, Ashulia urban wetland and Birulia urban wetland. The results of the research objectives are (I) The current scenario and existing role of selected urban wetlands have been identified according to the UWSF Model – 1, as degradation of biodiversity status, low resilience to climatic impacts, limited provisions of livelihood, inconducive policy and low institutional embeddedness of community (II) The challenges of urban wetland management and use in the selected urban wetlands have been identified according to the UWSF Model – 1, as wetlands water quality degradation by pollution through human interventions and natural activities, unplanned urban development, severe fish mortality, over population pressure, lack of community and stakeholder involvement on conservation and management, increase of over paved concrete areas in the city that are producing heat, destruction of aquatic ecosystems by decreasing DO, bed level reduction of water bodies through accumulation of sludge, lack of proper functioning of drainage infrastructures, lack of livelihood restrictions on the urban context, lack of awareness on policies and adequacy of policy regime among stakeholders, lack of proper implementation of policies in the water sectors for sustainable management, lack of awareness on valuation of water bodies, lack of sustainable conservation, maintenance and management of urban wetlands etc. (III) From the results of water quality parameter assessment, the selected urban wetlands are highly dominated by anthropogenic and natural activities and at serious risk for poor aquatic biodiversity and ecosystem enhancement in the city (IV) According to the UWSF Model – 2, the study identified that average DO concentration has been affected mainly by existing wetland management structures, water pollution from industrial effluent, population density, water pollution from sewerage effluent, air pollution and presence of surrounding shaded trees and vegetations in that order. From the analysis, this research showed that, if the number of total external factors decreases then the average DO concentration across urban wetlands increases. Conversely, if the number of total external factors increases, then the average DO concentration across urban wetlands decreases. Therefore, there is a strong relationship between the selected external factors and their influence on the average DO concentration across the selected urban wetlands. Therefore, sustainable policies and management plans for all these factors must be implemented for the selected urban wetlands respectively (V) Based on the overall finding and analysis, this research has proposed recommendations for sustainable conservation and management of urban wetlands in the capital. This information will further help to implement sustainable management of specific wetland areas in the city and throughout the country as well.

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List of Abbreviation

Abbreviation

AMC	Ahmadabad Municipal Corporation
BAPA	Bangladesh Poribesh Andolon
BBS	Bangladesh Bureau of Statistics
BCCSAP	The Bangladesh Climate Change Strategy and Action Plan
BFDC	Bangladesh Fisheries Development Corporation
BIWTA	Bangladesh Inland Water Transport Authority
BIWTC	Bangladesh Inland Water Transport Corporation
BOD_5	Biochemical Oxygen Demand
BUET	S Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CBO	Community Based Organizations
CDA	City Development Authority
CEGIS	Center for Environmental & Geographic Information Services
CNG	Compressed Natural Gas
COD	Chemical Oxygen Demand
COP	Conference of the Parties
DAP	Detailed Area Plan
DCC	Dhaka City Corporation
DEPC	Directorate of Environmental Pollution Control
DFID	Department for International Development
DMDP	Dhaka Metropolitan Development Plan
DNCC	Dhaka North City Corporation
DO	Dissolved Oxygen
DoE	Department of Environment
DoF	Department of Fisheries
DPSIR	Driving Force-Pressure-State-Impact-Response
DSCC	Dhaka South City Corporation
DWASA	Dhaka Water Supply and Sewerage authority
EC	Electrical Conductivity
ECA	Ecologically Critical Area
EIA	Environmental Impact Assessment
EQS	Environmental Quality Standard
ESA	Environmental Systems Analysis
ETP	Effluent Treatment Plant
GHG	Green House Gas
HELPA	Hebbal Lake Park Association
HIE	Heat Island Effect
IUCN	International Union for Conservation of Nature
IWFM	Institute of Water and Flood Management
IWM	Institute of Water Management
IWM	Institute of Water Modeling
JICA	Japan International Cooperation Agency
LGED	Local Government Engineering Department
LGIs	Local Government Institutions
LGRD	Local Government and Rural Development
MoA	Ministry of Agriculture

MoEF	Ministry of Environment and Forest
MoFAR	Ministry of Fisheries and Animal Resources
MoL	Ministry of Land
MoW	Ministry of Works
MoWR	Ministry of Water Resources
NBSAP	National Biodiversity Strategy and Action Plan
NEMAP	National Environment Management Action Plan
NWP	National Water Policy
OECD	Organization for Economic Cooperation and Development
PLDC	Private Land Development Companies
PM	Particulate Matter
POBA	Poribesh Bachao Andolon
PSR	Pressure – State – Response
PWD	Public Works Department
RAJUK	Rajdhani Unnayan Kartipakkha
RHD	Roads and Highways Department
RPMC	River Pollution Mitigation Committee
SDGs	Sustainable Development Goals
SP	Structural Plan
SPARSO	Bangladesh Space Research and Remote Sensing Organization
STP	Sewage Treatment Plant
SWO	Special Works Organization
TDS	Total Dissolved Solid
UAP	Urban Area Plan
UP	Union Parishad
USA	United States of America
USEPA	United States Environmental Protection Agency
USIP	Uttara Sanitation Improvement Project
UWSF	Urban Wetland Sustainability Framework
WARPO	Water Resource Planning Organization
WHO	World Health Organization
WWD	World Wetlands Day

CHAPTER - I

INTRODUCTION

1.1 Background and the Problem

Urban wetlands offer a different function as nature preservation, microclimate cooling, a space for recreation and overall urban sustainability in a city. But at present, these wetlands have been degrading and facing a lot of challenges as urban development, growth of population, pollution, improper drainage, over consumption of water, introduction of exotic species, hydrological alteration, excessive nutrients contamination, climate change etc. Another way, these wetlands are not involved in urban planning decisions in the city normally, that frequently leads to weak governance (Alikhani et al., 2021).

According to different international study, conservation and management of these wetlands has become an international scientific problem (cited in Gong et al., 2021). Wu and Murray, in (2003), observed that, proper management of the changing urban environment is considered a requirement to attaining sustainability. Therefore, these urban wetlands need proper restoration, protection and management urgently (Alikhani et al., 2021). In this respect, involvement of individual citizens as well as stakeholders on the sustainable management of urban wetland resource can be a suitable option to combat these recent global challenges. Therefore, there is a countless need for further research on the importance of peoples' social perception of wetlands on the urban context (Alikhani et al., 2021). In this connection, a study observed by Kudumba, in (2022), indicated that, additional research should be needed with the involvement of stakeholders in African cities in order to achieve sustainable urban wetland management to reinforce connecting policies and relevant organizations as well. In this way, urban wetland policies should recover these water courses as these policies are important to achieve the sustainability of the city (Alikhani et al., 2021).

However, there are few studies have been done still now on the sustainable management of urban wetland on the global context. One study identified by (Saadati et al., 2013), for sustainable management of wetland ecosystem of the Hamoun wetlands in Sistan and Baluchestan Province in Iran which are selected as a case study. This study used Driving Force-Pressure-State-Impact-Response (DPSIR) approach to identify the problems faced by wetlands and develop proper indicators for policy-making. Results indicated some challenges as high temperature and low precipitation, restricting the Hirmand River inflow by Afghan Government, introducing exotic fish species, desertification and wind erosion, extinction of fish and bird species and soil salinity etc. One study observed by Andab and Sheara, in (2009), in the Mexico. In this study, Pressure – State – Response (PSR) model is used as a management tool in developing a sustainability plan for the Mexico lake and its basin that developed by the Organization for Economic Cooperation and Development (OECD, 1993). Different problems identified in this study as sewage contamination (nutrients and bacteria), agricultural runoff (pesticides, nutrients, bacteria and sediments), deforestation, erosion and overuse of the water resource in the basin etc. The economic and ecological sustainability of the lake interrupting because of the increase in urban population and associated anthropogenic activities in the basin and because of the endorheic (closed basin) features and shallowness of the lake. Climate change in the basin has also had a strong impact on the lake due to deforestation (Andab and Sheara, 2009). The poor management practices of the Atenquique paper mill have resulted in loss of regional biodiversity due to habitat destruction, severe degradation of water quality in rivers, lack of a culture of sustainability, lack of enforcement etc. (Andab and Sheara, 2009). One study observed by Kudumba, in (2022), in the place of Harare, Zimbabwe. Analyzed by a critical review of legislation, city by-laws, a case study analysis of Harare and an analysis of a plethora of reports. The research showed that, protecting and managing urban wetlands is still difficult, particularly in rapidly urbanizing places like Harare. Identified challenges are as growing housing sector, increased urban agricultural operations and rising industrial growth etc. Another study conducted by Mylopoulos, in (2003), in Greece with questionnaire survey. Results investigated some challenges are water shortages, which occur mainly during the summer and especially on the islands, high water consumption rates, a wide variety of water pricing policies, lack of public participation, sectoral and fragmented rather than integrated water management and the fact that water is considered to be a social commodity etc.

Dhaka, the capital city of Bangladesh is also no exception on the perspective of urban wetlands. This city was well-known for its water systems as other cities in the world (Sharmeen, 2014). At present, the sustainability of water bodies has been deteriorating (Rahman et al., 2012). The surface water quality is not sustainable for aquatic wildlife as well as for human well-being (Beier, 2008). These water bodies have been polluting for unplanned urban and industrial development (Sultana et al. 2013). According to The Daily Star report, in (2008), at least 7000 tons of solid wastes are generated in and around the Dhaka City Corporation area every day. Only 50% of municipal waste is collected by the city corporations. As a result, maximum waste is discarded into the water bodies which degrading the quality of water at last (Hasan, Shahriar and Jim, 2019) (cited in Uddin et al., 2023).

In addition, nearly 80% of the total industries do not have treatment plant in the city and these water courses has been received poorly treated toxic effluents discharge (Sultana et al., 2013). Huge volume of toxic wastes from industrial areas and sewage lines degrading the surrounding rivers of the city (Islam et al., 2006). About 60,000 m3/day of toxic wastes discharged from nine industrial clusters as Hazaribagh, Tejgaon, Narayanganj, Ghorashal, Savar, DEPZ, Tongi, Tarabo and Gazipur areas of the city. These wastes have been disposed into the surrounding rivers as Buriganga, Turag, Tongi Khal, Balu, Sitalakkhya and Dhaleswari etc. (River Pollution Mitigation Committee (RPMC), 2008). Bangladesh Poribesh Andolon (BAPA) reported that, a total of 6000 tons of liquid waste per day has been received by the Buriganga River and half of them comes from Hazaribagh tanneries (The Daily Star, 2010). Most industries of more than 7000 are located in three main areas of the Hazaribagh, Tejgaon and Dhaka-Narayanganj-Demra dam areas besides surrounding rivers (Roy, 2009) (cited in Islam et al., 2015). Surface water quality of the city have been monitored by the Department of Environment (DoE), Institute of Water Management (IWM) and Water Resource Planning Organization (WARPO). Results indicated continuous decline of water quality of the surrounding lakes and rivers which are close to industrial areas (Rahman and Alam, 2005) (cited in Islam et al., 2010).

Another way, there is only one sewerage treatment plant at Pagla which is currently operating below capacity because of sewerage system failures (DoE and LGED, 2010). Maximum water bodies found very high BOD, COD and microbial contamination indicated discharge of poorly treated industrial effluents and other wastes (Hasan, Shahriar and Jim, 2019) (cited in Uddin et al., 2023). A review study conducted by (Uddin et al., 2023), with 50 relevant published reports on urban wetland as lake water quality status in the city. Study showed that, most of the lakes have been suffering from lower Dissolved Oxygen (DO) levels than the standard limit for aquatic organisms and contained a higher number of fecal coliforms (as *Vibrio cholerae*, *Escherichia coli*, *Salmonella spp*., *Klebsiella spp*., *Enterobacter spp*., *Shigella spp*., *Listeria spp*. etc.) than the WHO standard limit (0 cfu/100 mL for drinking water).

Other threats are, Dhaka has more than 20 million permanent and temporary dwellers and a 3.6% population growth rate per annum (World Population Review, 2020). Overall, the quality of water bodies has been degrading for lack of implementation of regulations and lack of institutional concern in the city (DoE and LGED, 2010). Another way, for the management of wetlands in Dhaka city, there is no single authority, therefore creating a lack of coordination among the relevant institutions (Khan, 2001). Therefore, water management must be the first concern for any development in Dhaka city (Sultana et al., 2009). However, a feasible participatory practice should be designed consisting of different stakeholders (Uddin et al., 2023).

Most previous studies on urban wetlands have been done in Dhaka city on morphological, hydrological changes, transformation of water bodies, restoration on planning aspects, water quality features etc. However, there are very few studies have been done still now on the sustainable management of urban wetland in Dhaka city. For an example, one study conducted by (Islam et al., 2012), investigated the challenges faced by Dhaka city in managing urban lakes. This study used Driving Force-Pressure-State-Impact-Response (DPSIR) Framework and Environmental Systems Analysis (ESA) tools for the analysis. The results indicated, Pressure as industrial disposal, municipal waste, population growth, lake filling and agricultural runoff. Responses included, improved management policies, public awareness and municipal sewage etc. for the management of wetland. Another study identified by (Karim et al., 2015), on Gulshan Lake in Dhaka city. (DPSIR) monitoring model has been proposed for the management. In this study, different challenges have been identified as demographic pressure, urban development, encroachment of land, land filling, discharge of domestic and industrial waste etc. Pressure as industrial disposal, municipal waste, population growth, lake filling and agricultural runoff etc. Responses included, improved management policies, control of industrial waste discharge, improvement of public awareness, improve municipal etc. for the management of wetland.

From the above literature it’s shows that, many studies have been done on conservation and management of wetlands, but a very few studies were conducted particularly on existing status, role and the challenges of urban wetland management and use concerning sustainability paradigm in the selected urban wetland in Dhaka on stakeholder perceptions in social research study that remain largely unexplored. Under these circumstances, considering all the constraints and challenges the present study aims at exploring the insight of sustainable urban wetland management in Dhaka city, their current status, existing role and challenges concerning selected urban wetland according to ‘Urban Wetland Sustainability Framework (UWSF) Model – 1’ to develop a better conservation and management concept and strategies in proposed study area. This study will serve as a source of baseline information and future planning for future researchers interested on similar wetlands in the country. The study may inform the policy related questions to be able to consider many challenges of the wetlands management in the capital.

Water bodies are vital for cities (Xiao et al., 2022). Despite its importance, water is the most poorly managed resource in the world (Fakayode, 2005) (cited in Phiri et al., 2005). The sixth objective of the Sustainable Development Goals 22 (SDGs) is sustainable water conservation and management (Xiao et al., 2022). While assessing the sustainability of these water resources, water quality plays an important role (Juwana et al., 2010). The water quality of urban water bodies is often negatively affected by rapid environmental changes when exposed to external stressors from the atmosphere, their watersheds, groundwater and most importantly anthropogenic effects (Garn et al., 2003) (cited in Phiri et al., 2005). Therefore, the measurement of physico-chemical and biological parameter of water quality is a key tool for effective sustainable management plans of water bodies (Dey et al., 2021). Among water quality parameters, Dissolved Oxygen (DO) levels have been used as a key indicator of the health of a water body. Therefore, understanding DO dynamics is important for water quality management to maintain aquatic ecosystem health (Xu, 2014).

However, there are very few studies have been done still now on the external factors affecting and how these factors affecting the variation of Dissolved Oxygen (DO) concentration across urban wetland on the global context for sustainable urban wetland management. For an example, a doctoral dissertation research in Cleveland State University, (USA), conducted by Huhnke, in (2018). The main purpose of the study is to produce a regression model by selecting USEPA QUAL2K model to identify both external and internal factors affecting minimum Dissolved Oxygen (DO) level in River water and the scale of effect. The regression model identified that, the factors affecting minimum Dissolved Oxygen (DO) concentration in River water are as 'municipal wastewater treatment plant effluent BOD', 'municipal wastewater treatment plant effluent discharge Q', 'River water discharge Q', 'River water temperature' and 'municipal wastewater treatment plant effluent DO' in that order. (Xu et al., 2023), investigated how the anthropogenic factors influence the Dissolved Oxygen (DO) concentration in surface water over three decades in eastern China by selecting a River Delta plain with collecting 35 years of data on water quality. The study results showed that, the impulsive perturbations of phosphate fertilizer consumption, motor vessel number and precipitation minimally increase DO level and impulsive perturbations of Gross Domestic Product causes drop of DO level.

Most previous studies on urban wetlands in Dhaka city explored on different status of water quality as well as limnological aspects, pollution sources, causes and relevant recommendations for the future management etc. However, there are very few studies have been done still now on the external factors affecting and how these factors affecting the variation of Dissolved Oxygen (DO) concentration across selected urban wetland on the Dhaka city context. Therefore, this research further tried to identified these issues according to 'Urban Wetland Sustainability Framework (UWSF) Model – 2' as well.

1.2 Objectives of the Research

Under these consequences, the study aims at fulfilling the following broad objectives:

1. To explore the current scenario and existing role of urban wetland with a special focus on the selected urban wetland in Dhaka.

2. To identify the challenges of urban wetland management and use in the selected urban wetland in Dhaka.

3. Assessment of water quality parameter tests on urban wetlands for identifies the aquatic biodiversity and ecosystem conservation capabilities in selected urban wetland in Dhaka.

4. To identify the external factors and how these factors have been influencing the variation of Dissolved Oxygen (DO) concentration across selected urban wetland in Dhaka.

5. Based on the overall observations of the study, to make recommendations for sustainable conservation and management of urban wetlands in selected urban wetland in Dhaka.

1.3 Research Questions

1. What are the current status and existing role of selected urban wetlands according to the Urban Wetland Sustainability Framework (UWSF) Model - 1?

2. What are the challenges of selected urban wetlands management and use according to Urban Wetland Sustainability Framework (UWSF) Model - 1?

3. What are the results of water quality parameter assessment on selected urban wetlands for identifies aquatic biodiversity and ecosystem conservation capabilities?

4. What are the external factors and how these factors have been influencing the variation of Dissolved Oxygen (DO) concentration across selected urban wetlands in Dhaka according to Urban Wetland Sustainability Framework (UWSF) Model - 2?

5. What are the recommendations for sustainable conservation and management of selected urban wetlands according to Urban Wetland Sustainability Framework (UWSF) Model – 1 and 2?

1.4 Limitations of the Research

1. This research is mainly based on stakeholder perceptions. However, detailed scientific data on such biodiversity (documentation) and climate change impacts was not collected.

2. There were limits of time and resources as the study did not have external funding.

3. This study focused on a few selected urban wetlands. Although the studied wetlands were carefully selected based on a clear set of rationale, the study does not claim to be representative of all the complex dimensions of wetland management.

1.5 Clues on Further Research

1. There are so many urban wetlands in Dhaka city as well as in different divisions except these selected urban wetlands. Similar types of studies can be carried out in those areas and present study can be a guideline for that future research.

2. Different information documented through this present study in relation to Urban Wetland Sustainability Framework (UWSF) Model - 1 for sustainable urban wetland management were less documented previously as a whole. Therefore, present research can be an example for future study.

3. As wetland resource dependent livelihood based local people (fisherman, farmer, boatman etc.) have better knowledge on each wetland, therefore involvement of those stakeholders can be a good example for sample selection for further research.

4. Further study can be conducted to find out the total economic value (direct and indirect values) of different urban wetlands in Dhaka city.

1.6 Organization of the Research

This thesis is divided into nine chapters. The first chapter is the introduction, which provides the background and the problem, the objectives of the research, research questions, research limitations, future research directions and organization of the research. The second chapter provides the literature review and analytical framework. The third chapter outlines the methodology and study area used for analysis of data, explains the research procedure and introduces the study areas. The fourth chapter provides finding and analysis - 1. The fifth chapter is the core of the thesis which provides finding and analysis - 2, a brief background of the study areas and elaborates the empirical evidences with its analysis and interpretation. The sixth chapter provides finding and analysis - 3, a detail water quality assessment result. The seventh chapter provides finding and analysis - 4. The eighth chapter provides the summary of the study (chapter – wise). The ninth chapter draws to the conclusions and recommendations with the broad outcomes of the research.

1.7 Concluding Remarks

This chapter discussed the background and the problem of the research. It further stated the objectives and set the research questions addressing the scope of the study as well as its limitations and future research directions. The study also describes the organization of the thesis. The whole study critically looks into the facts, that determine the status, role, and challenges of urban wetland management in terms of sustainability with a particular reference on selected urban wetlands in Dhaka city.

CHAPTER - II

LITERATURE RIVIEW AND ANALYTICAL FRAMEWORK

This chapter discussed a review of selected literature on the main theme of the research. The main purpose of this chapter is to review a conceptual overview, urban wetlands in global and Dhaka city context, relevant institutions and policies connecting urban wetland management in Dhaka city and develop an analytical framework for sustainable urban wetland management.

(I) CONCEPTUAL OVERVIEW

This section discussed a review of a conceptual overview.

2.1 Urban Wetland

Urban wetlands are the most important near-natural spaces in urban landscape units, including different urban lake wetlands, swamp wetlands and estuarine coastal wetlands, which are distributed in urban areas (Guangyou et al., 2004). According to Ramsar Convention on wetlands (World Wetlands Day, 2018), '*Wetlands are land areas that are flooded with water, either seasonally or permanently and these wetlands are found in and around cities or their suburbs. These wetlands include rivers and their flood plains, lakes and swamps as well as coastal variants such as salt marshes, mangroves and coral reefs'* (World Wetlands Day, 2018).

2.2 Sustainability

According to the World Commission on Environment and Development (1988), sustainability is a development which '*meets the needs of the present without compromising the ability of future generations to meet their own needs*'. Thus, Sustainability is the utilization and management of the present resources with the objective to ensure fair share of resources and a quality environment for the future generations. That is why, any policy, program or project which compromises human health and well-being cannot, by this definition be counted as sustainable (Bashar, 2013).

2.3 Biodiversity

Biodiversity means from all sources including the variability among living organisms, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems (Bashar, 2013). In fact, biodiversity is a composite of genetic information, species and ecosystems (Bashar, 2013).

2.4 Climate Change

Climate is simply the weather that is dominant or normal in a particular region; the term climate includes temperature, rainfall and wind patterns. Geography, global air and sea currents, tree cover, global temperatures and other factors influence the climate of an area, which causes the local weather (Bashar, 2013). This climate change may be occurred due to external forcing and natural internal processes or to persistent human induced changes in the composition of the atmosphere or changed in land use etc. (Bashar, 2013).

2.5 Community Livelihood

The Department for International Development (DFID) (1999) defines a livelihood as the capabilities, assets (including both material and social resources) and activities required for a means of living. Wetland ecosystems can provide opportunities for employment as livelihood development of wetland community people, renewable freshwater, food and nutrition, fuel, fodder, transportation and irrigation which contribute substantially to the socio-economic life of poor people (Islam, 2010; Nishat, 1993).

2.6 Wetland Management

According to the Ramsar Convention (2005), the wise use of wetlands and their surrounding landscapes is defined within the context of sustainable development with an emphasis on the maintenance of their ecological character and the implementation of ecosystem approaches. Thus, a sustainable wetland management and its overarching goal is to ensure sustainability in the way wetlands are utilized and managed (BEMP, 2004c).

2.7 Integrated Wetland Assessment Toolkit, IUCN

An 'Integrated Wetland Assessment Toolkit', methodology is required to determine the full importance of a wetland. This toolkit sets out a process for integrated assessment and provides a set of methods that can be used to investigate the links between biodiversity, economics and livelihoods in wetlands and to identify and address potential conflicts of interest between conservation and development objectives (Baginski et al., 2009). It is intended to help overcome the current methodological and information gaps in wetland assessment, thereby facilitating the factoring of wetland values into conservation and development decision-making and management planning. It can be applied to all sorts of wetlands and at all scales (Baginski et al., 2009).

2.8 Water Quality

Water bodies are the most valuable component among all natural resources which is essential for the survival of all living organisms in the aquatic broad ecosystems of environment. Different aquatic species of these water bodies have great importance in the biodiversity and food chain by providing rich nutrient for the aquatic life and may affect health of wildlife and humans. Water quality of these water bodies has been changed and affected by both natural and human activities. A variety of human activities as urban and industrial development, agricultural activities, mining and recreation, potentially significantly alter the quality of natural waters. Therefore, the key to sustainable water resources is, to ensure that the quality of water resources is suitable for intended uses (Terra Daily, 2006) (Kabir, 2014).

(II) URBAN WETLANDS IN GLOBAL AND DHAKA CITY CONTEXT

This section describes a review of selected literature on current scenario, existing role as well as challenges of urban wetland management and their use keeping global and Dhaka city in the context. The discussion is organized into different steps in linking with the objectives of the research.

(A) GLOBAL CONTEXT

2.9 Role of 'Urban Wetlands' on the Global Context

According to Ramsar Convention on wetlands (World Wetlands Day, 2018), '*Wetlands are land areas that are flooded with water, either seasonally or permanently and these wetlands are found in and around cities or their suburbs. These wetlands include rivers and their flood plains, lakes and swamps as well as coastal variants such as salt marshes, mangroves and coral reefs'* (World Wetlands Day, 2018). The first cities sprung up in the wetland floodplains of the Tigris and Euphrates rivers. Early settlers could practice agriculture, access water and transport their goods on these floodplains of fertile plains. During Hurricane Sandy, wetlands averted $625 million in property damage in coastal areas of the US (World Wetlands Day, 2018). Following the severe storms and the damaging floods that hit the Caribbean, the USA, Bangladesh and Nepal in (2017), more cities recognize the vital role of urban wetlands as well (World Wetlands Day, 2018). So far when left intact or restored, 'urban wetlands make cities resilient, sustainable and livable' through main role by 'World Wetlands Day, (2018)' are as replenish drinking water, promote human well-being, reduce flooding, filter waste and improve water quality, improve urban air quality and enable people to earn a living etc. (www.worldwetlandsday.org).

Wetlands play a crucial role in providing different functions and there is increasing evidence of the importance of managing and restoring urban wetlands (Tong et al., 2007). (Costanza et al., 1997) estimates the total value of ecosystem services provided by these wetlands worldwide to be 15.5 trillion dollars per year, almost 46% of the total for all global ecosystems. In addition to these services, the most valued ecosystem service is the capacity of wetlands to improve water quality and mitigate the transport of pollutants (cited in Ye et al., 2018). A review of 29 urban case studies conducted on behalf of UN-Habitat demonstrated that these wetlands provided a greater number of benefits to citizens than other ecosystems (McInnes, 2013) (Figure – 2.1 and 2.2).

Figure – 2.1: Existing role of urban wetlands; local climate regulation, recreation, culture and a sense of place: Xi'an, China. (Source: McInnes, 2013); (p - 7)

Figure – 2.2: The London Wetland Centre, United Kingdom, delivering multiple roles within a major urban landscape (Source: McInnes, 2013); (p - 8)

2.10 Current Scenario, Existing Role and Challenges of 'Urban Wetlands' Management and their Use on the Global Context

At present, urban wetlands are contaminated and the area gradually shrinking with the continuous expansion of the process of urbanization. Studies in the 'US Department of Agriculture' show that urbanization involves both the encroachment and destruction of wetlands, and the United States has lost 58 percent of its wetlands (Ye et al., 2018). With the development of the city, a large number of industrial waste water, domestic sewage and chemical fertilizers, pesticides and other harmful substances were discharged into rivers and other urban wetlands, causing serious damage to wetland biodiversity (Ye et al., 2018). In the world's freshwater species, half of the species are threatened by extinction in urban wetlands (Ramachandra et al., 2005).

The discharge of industrial waste water and the loss of pesticides directly lead to the enrichment of aquatic organisms and the accumulation of harmful substances such as heavy metals in aquatic organisms. The discharge of domestic sewage and the loss of chemical fertilizers lead to eutrophication of water bodies so that the entire habitat deteriorated and caused the loss of biodiversity as well (Ye et al., 2018). Another way, most of urban wetlands are seriously threatened by conversion to non-wetland purposes, encroachment of drainage through landfill, hydrological alterations and over-exploitation of their natural resources (Ramachandra, 2009). All these challenges affecting in decreased water transparency, dissolved oxygen consumption, affecting the appearance of water and aquatic organisms grow and even endanger human health (Ramachandra et al., 2005) (Figure – 2.3).

Figure – 2.3: A degraded urban wetland, Rufisque, Senegal. (Source: McInnes, 2013); (p - 11)

2.11 'Urban Wetlands' Adoption Towards Achieving Sustainable Development on the Global Context

From the very beginning (from 1971), globally the Ramsar Convention on Wetlands provides the framework for the conservation and wise use of all wetlands through local and national actions and international cooperation, as an involvement towards attaining sustainable development throughout the world (www.ramsar.org). This Convention adopt 'urban wetlands' concept in different international platform in different years are as follows:

2.11.1 Resolution XI.11 (Principles for the Planning and Management of Urban Wetlands)

In the 11th Meeting of the Conference of the Parties COP11 to the Convention on Wetlands (Ramsar) in Bucharest, Romania, in July 2012. Resolution XI.11 was adopted on the *'Principles for the planning and management of urban wetlands'*. At this Resolution XI.11, set out a clear set of five policy principles which governments, from national to local need to consider and implement when developing policies that jointly address urban planning and management and the wise use of wetlands (RAMSAR BUCHAREST, 2012). In addition to these five policy principles, Resolution XI.11 also set out practical principles which should be considered when seeking to deliver sustainable urban development in combination with better maintenance and enhancement of wetlands (RAMSAR BUCHAREST, 2012). Among these principles for the planning and management of urban wetlands, ‘Policy – 4’ is related to present research as ‘stakeholder engagement’ on sustainable urban wetland management that have been applied and are discussed as follows (Table – 2.1):

Table – 2.1: Policy and Practical Principles of Resolution XI.11 on ‘Urban Wetlands’

Resolutions	Policy principles	Practical principles
Resolution XI.11 (Principles for the planning and management of urban wetlands)	**Policy - 4**: The full participation of indigenous and local communities, municipalities and government sectors involved in urban spatial planning and wetland management decision-making is vital to creating sustainable urban settlements.	Stakeholder engagement: inclusivity, empowerment and participation of local communities should be pursued with decision making decentralized to the lowest appropriate level.

[Source: (RAMSAR BUCHAREST, 2012)]

This Resolution XI.11 confident that, with good planning and management, cities can be a driving force for sustainable social and economic development for current and future generations; recognized that, urban populations offer significant opportunities for community participation in wetland management and restoration in their local environment etc. (RAMSAR BUCHAREST, 2012).

2.11.2 Participation of All the Stakeholders on ‘Urban Wetlands’ for Sustainable Management

Urban wetland is a natural ecosystem which located in high urbanization areas is always interfered by human activities (Jingfeng et al., 2011). Protection of urban wetlands, it requires the participation of ‘whole society’. This is also the responsibility and obligation that the public should bear (Macintosh, 2018). Urban local bodies have an effective and key role to play in safe guarding ecological sensitive areas like urban wetlands by adapting technological support for functions like identifying, monitoring and mitigating degradation with active participation of all the stakeholders. Responding to its multiple vulnerabilities, it is highly recommended to priorities the need for conserving the tangible and intangible benefits of wetlands (Depak et al., 2015).

(B) DHAKA CITY CONTEXT

This section describes a review of selected literature on urban wetlands in Dhaka city. The discussion is organized into different steps in linking with the objectives of the study.

2.12 Role of 'Urban Wetlands' on the Dhaka City Context

Dhaka city, the fastest growing urban city of Bangladesh, is situated in the central part of the country (Sultana et al., 2009). Urban water bodies always play a significant multi-faceted role in the city's development (Sultana and Chowdhury, 2013). There existed a large number of water bodies including rivers, khals, lakes and low-lying areas as wetlands in Dhaka city (Islam et al., 2010). The city is bounded by The Buriganga River on the south, Tongi Khal on the north, Balu River on the east and Turag River on the west (Hossain et al., 2009). This city also crisscrossed by numerous canals. In addition to that significant portion of land area of Dhaka is depressed land, low-lying land and flood plains (Islam, 2009). These low-lying lands reflect as wetlands around Dhaka work as natural retainers of storm water, act as natural drainage system and certainly help to maintain balance in the ecosystem. In addition to their environmental contributions, these wetland areas add to the scenic quality of the city as well (Islam, 2009). These wetlands play a vital contribution to this city's landscape from ancient time. In the past the city was regarded as the "Venice of the East" or the *"City of Channels"* (Dani, 1962). A few decades ago, there were numerous lowlands, khals and channels within and around the city that would drain the city efficiently (JICA, 1991). Canals of the city are used to be the connecting channels of the rivers surrounded by the greater Dhaka. But nowadays, the situation is completely different. The city is expanding in an unplanned and uncontrolled manner, has spread over the years in all directions that caused shrinkage of the water bodies and wetlands (Islam et al., 2010).

2.13 Current Scenario, Existing Role and Challenges of 'Urban Wetlands' Management and their Use on the Dhaka City Context

Landscape of Dhaka city one of the fastest growing mega cities in the world, is undergoing continuous changes and modifications due to progressive urbanization (Sultana et al., 2009). Rapid population growth creates extra pressure on the land of already overcrowded the city. Besides population, the city has been suffering from many waters related environmental problems. The city is expanding in an unplanned and uncontrolled manner, has spread over the years in all directions that caused shrinkage of the water bodies and wetlands (Islam et al., 2010). Unplanned urbanizations have been destroying the water-bodies and flow-paths causing rainfall-flooding and drainage congestion in many locations in the city (Sultana et al., 2009). As a result, each year the city dwellers suffer acute water logging problems during the rainy season (World Bank, 2007). Many areas in Dhaka city go under water during monsoon rains, being the primary drainage system are blocked in the city and cannot transfer the huge volume of storm water (Islam et al., 2010). The situation has turned very severe in recent years, and main streets now go under a meter of water after heavy monsoon shower (Islam et al., 2010).

Rivers around the city gets the storms drainage and other low grade (mostly households) liquid waste, and also liquid waste from the industries. These liquids and other pollutants have been polluting the river water (Sultana et al., 2009). Furthermore, the polluted water of huge quantity and biological and chemicals origin of city wastes is polluting the downstream wide-rivers, estuaries and the Bay of Bengal causing limitless degradation of biodiversity particularly the fresh, brackish and marine-water fishes, animals and plants etc. (feppcar.org, 2010). Pollution has become a great threat for the existence of aquatic lives in lakes, channels and khals as well as biodiversity and whole ecosystem. On the other hand, withdrawal of a great volume of ground water is leading the city towards high risk of earthquake (feppcar.org, 2010). Moreover, most of the canals have disappeared and banks of the surrounding rivers are encroached or grabbed gradually due to a number of reasons. The major causes are unplanned urbanization, encroachment, lack of co-ordination between government agencies, maintenance to the system and implement of pertinent laws (World Bank, 2007). In addition, there is no definite map or well-documented records of wetlands in the city (Islam et al., 2010). The land grabbers take this opportunity to encroach the wetlands (Islam et al., 2010).

(III) RELEVANT POLICIES AND INSTITUTIONS CONNECTING URBAN WETLAND MANAGEMENT IN BANGLADESH

This section describes a review of selected literature on relevant policies and institutions connecting urban wetland management in Bangladesh.

2.14 Urban Wetland Management in Bangladesh

Management and conservation of natural resource is a multifaceted field and a proper coordination among administrative sector legal authorities, effective regulation and policies, different stakeholder and local people’s support, it can be successfully conserved. In order to achieve sustainable management of urban wetlands and water bodies in any country, effective policies, regulations and different institutions are necessary. Wetland related laws, policies, plans and institutions in Bangladesh are discussed below:

2.14.1 Acts, Policies, Strategies and Action Plans on Urban Wetland Management

There is no specific legislation relating to wetland conservation. Various acts, ordinances, and regulations have been promulgated for the purpose of conserving natural resources and several of these pertain to wetlands in Bangladesh. Some of laws, acts, policies, action plans on urban wetland management are as Urban Water Body Protection Law, 2001; Environment Conservation Act, 1995; Environment Conservation Rules, 1997; Water Body Conservation Act, 2000; Wetland Protection Act, 2000; The Town Improvement Act, 1953; Water Supply and Sewerage Authority Act, 1996; The Industrial Policy, 1999; National Environment Policy, 1992; National Water Policy, 1999; National Fisheries Policy, 1998; National Biodiversity Strategy and Action Plan (NBSAP); National Environment Management Action Plan (NEMAP); Dhaka Metropolitan Development Plan [DMDP 1995-2015]; Detailed Area Plan [DAP] etc. (Akonda, 1988; Chakraborty, 2012; Islam, 2009; Mowla, 2010; Saha, 2012; Clemett, 2000; Khan, 2000; COUNTRY REPORT FOR CENTRAL ASIAN FLYWAY OVERVIEW: BANGLADESH, 2005). Beside these national policies, laws and regulations, Bangladesh is signatory of Ramsar, CITES, CMS, etc. (Chakraborty, 2012).

2.14.2 Institutions Involved with Urban Wetland Management

Bangladesh has the highest wetland to total land ratio in the world (Haq et al., 2004). Almost half of the area of Bangladesh consists of wetlands (Haq et al., 2004). In 1990s, the nation realized the needs of resource management seriously and from then the management and conservation of those water bodies got priority (Chakraborty, 2012). Though the status of nations wetland management initiatives is not in satisfactory level, but in some cases the success is appraisable and can be followed for management of different socio-economic and ecological contest and with adaptation if necessary (Chakraborty, 2012). Some of institutions that related to urban wetland management in Bangladesh are as Ministry of Environment and Forest (MoEF); Ministry of Land; Ministry of water Resources; Department of Environment (DoE); Department of Fisheries (DoF); Institute of Water Modeling (IWM); Center for Environmental & Geographic Information Services (CEGIS); Directorate of Environmental Pollution Control; Rajdhani Unnayan Kartipakkha (RAJUK); Department of Public Works; Dhaka Water Supply and Sewerage authority (DWASA); Dhaka City Corporation (DCC) etc. International NGOs like IUCN – The World Conservation Union; Bangladesh Environmental Lawyers Association (BELA); Wildlife Society of Bangladesh, Department of Zoology, Dhaka University; Zoological Society of Bangladesh, Department of Zoology, Dhaka University; Wildlife Biology Branches of the University of Dhaka etc. (Akonda, 1988; Islam, 2012; Chakraborty, 2012; Sharmeen, 2014; COUNTRY REPORT FOR CENTRAL ASIAN FLYWAY OVERVIEW: BANGLADESH, 2005).

(IV) ANALYTICAL FRAMEWORK

2.15 Analytical Framework - 1: Urban Wetland Sustainability Framework (UWSF) Model – 1

In this research, first analytical framework has been selected as 'Urban Wetland Sustainability Framework (UWSF) Model – 1' which followed by IUCN Integrated Wetland Assessment Toolkit described in Baginski et al., (2009). This toolkit provides a conceptual and methodological framework for addressing wetland management issues and founded on the premise that an integrated approach to assessment is necessary in order to generate information that is practically useful, and policy relevant, for wetland planning and management (Baginski et al., 2009). Developing a shared vision across stakeholder groups based on mutual respect and understanding and rooting the assessment in real world management goals and objectives, are both essential to give purpose to the assessment process, and to identify relevant management and policy related questions for the assessment to tackle (Baginski et al., 2009). Wetlands are connected with the broader landscapes in hydrological and ecological terms and also exist within a human context (Baginski et al., 2009). For understanding and managing wetland landscapes, the interlinked aspects of a wetland landscape are hydrology and topography of the physical wetland, biodiverse wetland ecosystems, ecosystem services to human communities both local and more distant, local livelihood systems and policies, governance, institutions and markets etc. This toolkit describes a framework for assessment which consists of different stages as management including stakeholders', the state of wetland, to identify development threats, to identify the past, current, future management and policy responses etc. (Baginski et al., 2009). Different aspects based on Bangladesh context in study areas have been selected among these interlinked aspects of wetland management for the present research. In this research, for 'Urban Wetland Sustainability Framework (UWSF) Model – 1', five attributes of sustainability followed by the toolkit is chosen that will provide the basis for investigating the existing status, role and challenges of urban wetland on management and use according to stakeholder's perceptions in the selected study areas that discussed in this section. The following attributes: contribution for biodiversity conservation and enhancement, resilience of wetlands to face the challenge of climate change impacts, contribution for community livelihood, adequacy of the policy regime, local acceptance and credibility of the role of relevant institutions are described as below:

2.15.1 Contribution for Biodiversity Conservation and Enhancement

Biodiversity describes the variety of life (which is the number and variety of organisms within a particular area) that is frequently used as a means to assess the health of biological systems. Wetlands plays an important role in the biodiversity conservation of a place. Besides used as crop and animal production, these water bodies also impact the public and the aquatic and terrestrial ecosystems (Cooper et al., 1998). These water bodies not only hold fisheries but also provide habitat for a wide variety of aquatic vegetation, birds and wildlife (Razzak et al., 2012). Different species of migratory birds and wildlife (amphibian, reptilian, birds, snails, turtle etc.) are found to be dependent on these wetlands. Not only the aquatic biodiversity, but many of wetlands and water bodies that dried partly in the line season supports different types of terrestrial and aquatic vegetation (Chakraborty, 2012). As wetland is standing or slow-moving shallow water body, rooted plants can grow over most of the bottoms. With the sun light as its energy source, different community of biological species of a wetland is distributed throughout its depth. As relatively small portion of water is in contact with the air, decomposition takes place on the bottom. Life in these water bodies, its distribution and adaptation are intensely influenced by the differences in oxygen level along with its depth, light, temperature, water quality (turbidity, hardness, mineral content, acidity) etc. Wetland's open water is dominated by phytoplankton (minute suspended organisms such as algae) that absorb sunlight to carry out photosynthesis thus and as food producers based upon which other life forms depend (The Daily Star, 2005).

2.15.2 Resilience of Wetlands to Face the Challenge of Climate Change Impacts

Climate change is the greatest environmental challenge of the world. As cities occupy many activities, they are particularly vulnerable to climate change and climate extremes (Hassan et al., 2014). Changes in urban areas impact climate, natural ecosystems, valuable agricultural lands and water resources which directly affect human health and well-being. Studies showed that inland water bodies can have important impacts on climate in various spatial scales (Bonan, (1995); Hostetler et al., (1994); Kinner, (2003); Lofgren, (1997); Long et al., (2007)) (cited in Sharmeen, 2014). As compared with vegetated land surfaces, inland water bodies play an important role in determining local and regional climates, primarily because of large differences in Albedo, heat capacity, roughness, energy exchange. Along with the evaporation effect, water is the best absorbers of radiation with a relatively high heat capacity. The most significant impact of large water bodies is that, they act as heat sinks. In other words, large water bodies store heat in warm periods and release it in cold periods as the thermal capacity of water is high (Sharmeen, 2014). For having this quality to regulate the urban temperature, architects and urban planners also use water bodies as design tools (Coutts et al., 2013). Climate change affects any urban area in two ways**,** through floods and heat stress. The melting of glaciers and snow in the Himalaya and erratic changes in temperature along with rainfall leads to more frequent flooding. The water logging and drainage congestion due to river floods and excessive rainfall during monsoon are the more contemporary issues in this regard (Alam and Rabbani, 2007). Wetland can contribute a vital function to combat against these floods and heat stress of climate change impacts as it plays important role in the hydrologic cycle; as it can receive, store and release water in various ways: physically (through ground water and surface water run-off) as well as biologically (through transpiration by vegetation) (Razzak et al., 2012). Wetlands can refill the aquifer and can enrich the source of ground water in this regard (Rafiq et al., 2014). Besides, according to environmental statistics, 10 percent of a city should be comprised with water bodies as they can reduce sound, air and noise pollution (Kumar and Dua, 2009). Urban wetlands or water bodies contribute a significant role on natural water purification. Natural wetland always acted as nature's own purification plant in the presence of different reed plant species (i.e. Sedges, Rushes and Irises) which help to purify the waste water in a natural way by reducing COD content of water, oxygenation, elimination of pathogens, ammonium degradation, degradation of nitrate, removal of phosphates and heavy metal. Moreover, urban water bodies play an effective role in microclimatic cooling of the urban area (Shahjahan and Ahmed, 2016).

2.15.3 Contribution for Community Livelihood

Wetlands as well as other water bodies play an important role in the ecology, economy and livelihood of a country. Being act as natural reserves of the water, these water bodies are the source of fisheries, aquatic vegetation and other biodiversity, irrigation, navigation and flood control etc. Different species of freshwater fishes are found in the inland water bodies of Bangladesh which offer tremendous scope and potential to augment fish production by adoption of culture-based fishery enhancement technique. Wetlands of Bangladesh are rich in biodiversity and these natural resources are the main livelihood options for millions of poor people (particularly the fisher community in the country) and provide great ecological, economic and social values in ensuring livelihood security (Chakraborty, 2012).

2.15.4 Adequacy of the Policy Regime

Enforcement of laws, regulation and policies plays an important role in case of conservation of any natural resources. Though several legal acts and planning policies are present regarding the protection of wetlands in Dhaka city and the strength or quality of these prevailing policies, planning documents, regulations and acts are quite adequate, their proper implementation is still absent (Islam, 2009). In particular, the current situation requires stricter enforcement of environmental clearance conditions, effluent standards for future sustainable management and conservation of water resource (BEMP, 2004c).

2.15.5 Local Acceptance and Credibility of The Role of Relevant Institutions

The institutional framework for management of Dhaka and its environment is disordered (BEMP, 2004c). RAJUK, RHD, DWASA, BWDB and DoE are the five public agencies directly involved to ensure protection of urban wetlands in Dhaka city. Besides these sectoral agencies, local government bodies such as Dhaka City Corporation (DCC), Pourashavas and Union Parishad have important role to play. Though Dhaka adopted the strategic planning approach, there seems less effort to reform the existing institutional structure as a functional one. Lack of commitment of the responsible people implementing the plan; absence of a proper working atmosphere to operate with authority and autonomy (as it is influenced by power structure); lack of coordination among the sectoral agencies towards a comprehensive goal; absence of public participation and wide gap between plan maker, user group and implementation authority are some of the problems and factors that are responsible for poor performance of these institutions (Islam, 2009). Moreover, overlapping of jurisdiction between many Government agencies is another serious problem often leads to inaction. There is no co-coordination between the planning and implementation of the activities and interventions of all stakeholders (BEMP, 2004c). Therefore, the wetlands in urban and peri-urban environments require appropriate planning and management to secure benefits which can further contribute in sustainable urbanization (Ramsar Convention on Wetlands, 2013). Following (Figure – 2.4) shows the Analytical Framework - 1 of the research:

Analytical Framework - 1: Urban Wetland Sustainability Framework (UWSF) Model - 1
(Note: The five attributes of sustainability are partially drawn on (Baginski et al., 2009))

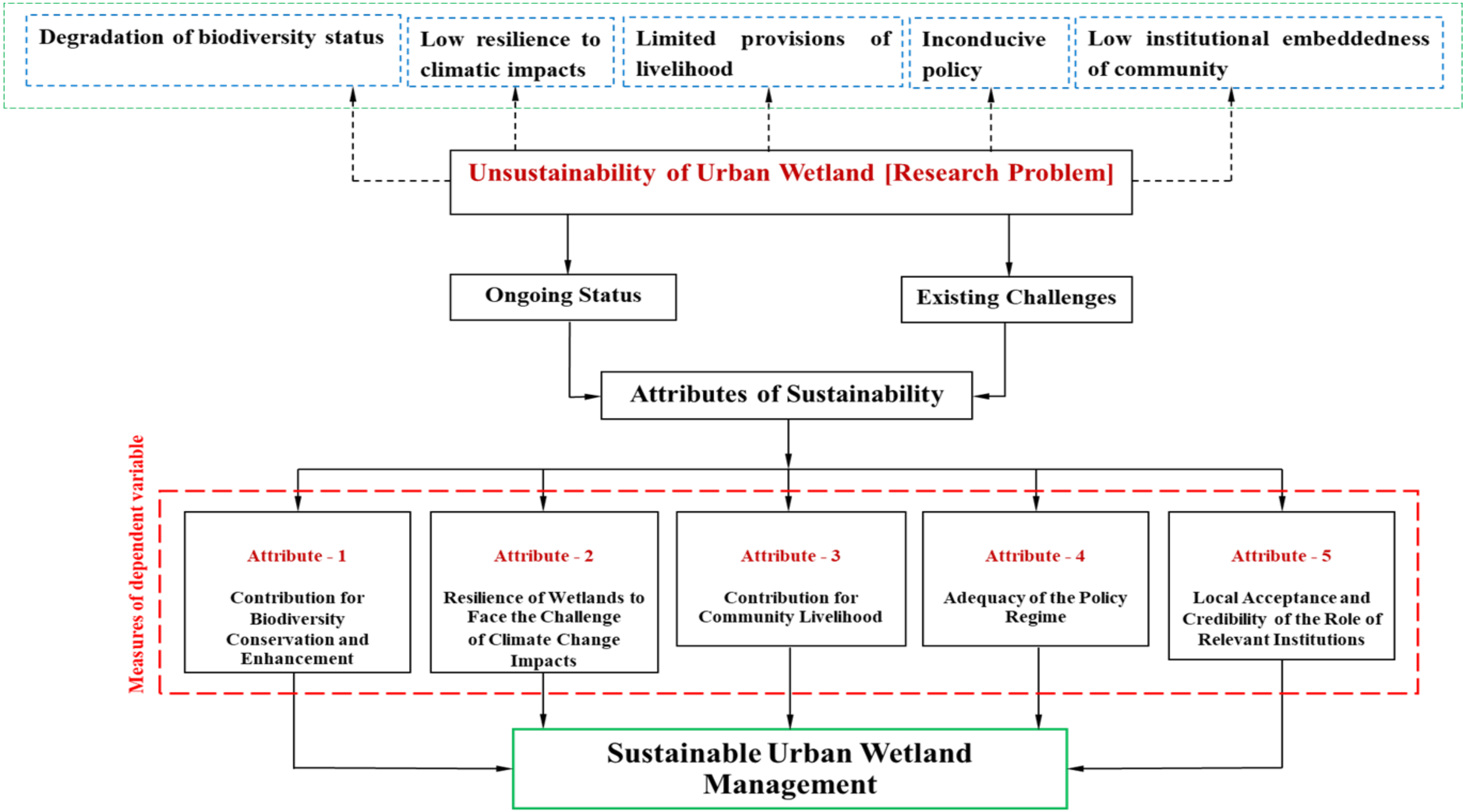

Figure – 2.4: Analytical Framework - 1 of the Research

2.16 Analytical Framework - 2: Urban Wetland Sustainability Framework (UWSF) Model - 2

In this research, second analytical framework has been selected as 'Urban Wetland Sustainability Framework (UWSF) Model - 2' (followed by *https://atlas-scientific.com*, (2021) and other articles) that will provide the basis for investigating the external factors and how these factors are influencing the variation of average Dissolved Oxygen (DO) concentration across selected urban wetlands. Total six external factors have been selected as water pollution from sewerage effluent, water pollution from industrial effluent, population density, presence of surrounding shaded trees and vegetations, air pollution and existing wetland management structures etc. are described below. (Figure – 2.5) shows the Analytical Framework - 2 of the research as follows:

2.16.1 External Factors Influencing the Variation of Dissolved Oxygen (DO) Concentration on Urban Wetlands

Dissolved Oxygen (DO) describes the amount of Oxygen (O_2) molecules that are dissolved in water that is affected by both anthropogenic (human activities) and natural factors. Naturally, water conditions such as salinity and temperature and too many aquatic organisms can affect DO levels. Humans also have an impact on DO levels in water from clearing land, runoff and sewage waste etc. (atlas-scientific.com).

2.16.1.1 Water Pollution from Sewerage Effluent

Discharge of emissions from improper sewage treatment plants and leakage of disastrous septic tanks may contribute significant quantities of organic materials and nutrients that produce Biological Oxygen Demand (BOD) (atlas-scientific.com).

2.16.1.2 Water Pollution from Industrial Effluent

Some industries release organic chemicals that require oxygen for decomposition (atlas-scientific.com). These end-of-pipe discharges are regulated under permit limits to protect receiving waterbodies (atlas-scientific.com).

2.16.1.3 Population Density

A study conducted by Misra and Tiwari, in (2014), the analysis of model shows that increase in human population intensify the depletion in concentration of Dissolved Oxygen (DO) in a water body. In this respect, human population constitute relevant factor for the increase in organic pollutants and eutrophication, which is even exacerbated in lentic ecosystems such as lakes, leading to a decrease in DO, thus affecting on the aquatic ecosystem.

2.16.1.4 Presence of Shaded Trees and Vegetations on the Bank of the Urban Wetland

Tree and plant removal along water bodies decreases shading contributing to increased water temperatures. As warmer water contains less oxygen, it can indirectly reduce DO levels in the surrounding water (atlas-scientific.com).

2.16.1.5 Air Pollution

According to (Thakur et al., 2020)…'Atmospheric pollution unswervingly influence the surface water bodies and change the quality of water' (Thakur et al., 2020). Among air pollutant, acid rain can harm the water quality of a river, lake and other water bodies (Canada.ca). According to (Qian et al., 2013)… 'Oxides of Sulphates and Nitrogen can cause acid rain to the water bodies and affect the water quality and the aquatic ecosystems' (Michaud, 1991) (cited in Qian et al., 2013).

2.16.1.6 Existing Wetland Management Structures

Existing wetland management structures of the study area have been selected as one of the external factors that described as follows:

2.16.1.6.1 Existing Status of Wetlands Management in Bangladesh

For the wetland resource management in Bangladesh, the Government put on strictly central, sectoral and top-down approaches of development (Khan, 2011). Different Government agencies as the Ministry of Water Resources (MoWR), Ministry of Environment and Forest (MoEF), Ministry of Fisheries and Animal Resources (MoFAR), Ministry of Agriculture (MoA), Ministry of Land (MoL) etc. are directly involved in resource management (Khan, 2011). For the wetland resource management, these organizations have been implementing policies and sectoral plans in the country (Khan, 2011). The Ministry of Works, the Department of Environment and the Fisheries Department have been involved on the maintenance of these wetlands, the Fisheries Department have been responsible for fish stocks, the ownership of these wetlands is the Ministry of Works (Rahman, 1989; Islam, 1993). In the country, the Department of Environment (DoE) responsible for the protection of aquatic resources and the environment of these wetlands (Islam and Kitazawa, 2012).

2.16.1.6.2 Existing Policies, Regulations, Plans, Acts, Laws of Wetlands Management in Bangladesh

Wetlands management is not addressed separately in the water management policy of Bangladesh (GOB, 1999; Qayyum and Islam, 2010). In the country, wetlands management at present are controls by the National Water Policy (NWP) (GOB, 1999; Qayyum and Islam, 2010). Some old acts as the Environment Policy, 1992; the Haor Development Board Ordinance, 1977 and Protection and Conservation of Fish Act, 1950 etc. are reliant on these National Water Policy (NWP) (Islam and Kitazawa, 2012). Wetlands have been given importance by these policies as 'rivers, lakes, canals, haors, baors, beels, roads and all other water bodies should be safe from pollution' (Islam and Kitazawa, 2012). To conserve and protect open water bodies, there are more than a score of regulations and policies in Bangladesh that are rivers and close water bodies (NEW AGE, 2018). Among them, the Natural Water Reservoir Conservation Act, 2000 that prevents water bodies being developed into high land is the prominent one and the Bangladesh Water Act, 2013, that involved used for management, protection and conservation, integrated development, distribution, abstraction and use of water resources (NEW AGE, 2018). Another way, by the National River Protection Commission Act, 2013, the National River Protection Commission have been formed as well (NEW AGE, 2018). Maximum of these regulations are recognized as lack of implementation on the encroachment of water bodies still now either open or close (NEW AGE, 2018).

2.16.1.6.3 Existing Challenges of Wetlands Management in Bangladesh

In Bangladesh, the management of wetlands is organizationally uneven (Chowdhury, 1987; Ali, 1990; Ahmed et al., 2008). Due to poor coordination and maintenance from different sectors, the pollution related problems demonstrated shortly and involved wetlands management in later (Chowdhury, 1987; Ali, 1990; Ahmed et al., 2008). In the use of these wetlands, the stakeholders involved which have different contradictory interests and agenda (Sadeq and Islam, 1993; Mirza et al., 2001). For an example, the Department of Environment (DoE) and residents of these wetland areas are involved in resolving the protection of biodiversity and problems on wetland degradation (Sadeq and Islam, 1993; Mirza et al., 2001). But it is not easy to resolve the difficulties without appropriate policy model meanwhile various stakeholders are involved in wetland activities (Islam and Kitazawa, 2012). So, it is significant to build up the awareness of public who are directly linked to these wetlands (Islam and Kitazawa, 2012). Various actors involved in wetland resources management and the absence of coordination among the organizations weakens the impartial decision-making processes and integrated resource management (Khan, 2011). In managing wetland resources, as many local institutions have been marginalized, become ineffective and on the traditional practices, stakeholders have inadequate or no role to play in the management system as well (Khan, 2011). In the decision-making process, present policy practice undermines the presence of local resource users as genuine stakeholders (Khan, 2011). Local people are persistently excluded from access and control over wetlands that largely depend on wetland resources (Khan, 2011). For sustainable resource management, providing local resource users institutional scope for participation in management system and rein-statement of the rights of local resource users in decision-making are urgently needed (Khan, 2011). Particularly, in tropical Asia, local people have a long practice of managing wetlands and to secure their livelihoods, these local people have been managed wetlands for centuries (Khan, 2011). This research highlighted the sustainable management of selected urban wetlands according to the Urban Wetland Sustainability Framework (UWSF) Model – 1 and 2 through stakeholder perceptions for identification of current status, existing role and challenges on management and use in the city of Dhaka as a case. The existing management structures of selected urban wetlands have been discussed as below:

2.16.1.6.4 Existing Management Structures of Selected Urban Wetlands

2.16.1.6.4.1 Study Area - 1: Dhanmondi Lake

For looking after the various aspects, Dhanmondi Lake has been managed by several authorities. For making the lake a pollution-free recreation zone, some reconstruction works were carried out from 1998 to 2001 around Dhanmondi Lake (Chowdhury, 2003b). The ownership of the lake is the Ministry of Works (MoW), fishery development of the lake is in charge by Fisheries Department, for the improvement of the lake, Dhaka City Corporation, being the principal civic body that is mainly concern about the lake, for the protection of aquatic resources of the lake and to get proper environment, the Department of Environment (DoE) have the main responsibility (Razzak et al., 2012; Islam, 2015). In 1996, as an outcome of the increased public access by the inauguration of the “Bangabandhu Smriti Angan”, the Government took development initiative for Dhanmondi Lake (Alam, 2015). To get a pollution free recreational zone, some reconstruction works have been done during the year 1998 to 2001 in this lake area (Sharmeen, 2014). Further, under the ministry of LGRD, Dhanmondi lake have been developed by the Dhaka City Corporation (DCC) as a project named ‘Dhanmondi Lake and Lakeside Area Development Project’ (Sultana and Chowdhury, 2013). Another way, the Dhaka South City Corporation (DSCC) has been working on different projects recently for the restoration and development in this Dhanmondi Lake and park area (Mithu, 2019).

2.16.1.6.4.2 Study Area - 2: Gulshan-Baridhara Lake

Gulshan-Baridhara Lake has been maintained mainly by the Rajdhani Unnayan Kortripokhho (RAJUK), the Department of Environment (DoE), the DWASA etc. with implementing of different Government projects in this area which have been declared as an ecologically critical area (Sabit, 2011). This lake is under the Dhaka North City Corporation (DNCC) (Rahaman, 2017) and a strong community institution named Gulshan Society have been responsible for this lake as well (Sultana and Chowdhury, 2013). During the year 2010, a project named ‘Gulshan-Banani-Baridhara Lake Development project’ have been implemented in this area by the Rajdhani Unnayan Kortripokhho (RAJUK) which have been extended later until the year 2022 as the condition of the lake is still challenging (Siddiqui and Islam, 2021). According to the report of DWASA, main challenges faced in this lake are lack of sewerage systems and release of untreated surrounding factory effluent (The Daily Star, 2007).

2.16.1.6.4.3 Study Area - 3: Hatirjheel Lake

Haitrjheel Lake located at the central part of Dhaka city and is a projecting depression within the Dhaka metropolitan area (Mustafa, 2021; Rahaman, 2017). This lake is under the Dhaka North City Corporation (DNCC) (Rahaman, 2017) and served as a significant role on retention of natural drainage systems from surrounding vast areas (Miah et al., 2017). This lake can retain nearly 3.06 billion liters of water throughout dry season and nearly 4.81 billion liters of water throughout the monsoon which has been marked as a largest urban water body in Dhaka city (Hossain, 2020). Haitrjheel Lake has been maintained mainly by the Rajdhani Unnayan Kortripokhho (RAJUK) (Siddiqui and Islam, 2021). Among other organizations, Bangladesh Army, Special Works Organization (SWO) and others are had been working on this lake (Rahaman, 2017). Another way, there are large on-going different Government projects that have been working on the management of this lake area from long time for different unusual environmental challenges throughout the year (Peeters and Shannon, 2009). According to the Housing and Public Works Minister, Engineer Mosharaf Hossain, (according to the BSS reports), Rajdhani Unnayan Kortripokhho (RAJUK) has been engaged a project that including 410 crores of taka for this lake and the key purposes of this project are cleansing of polluted water, enabling water retention in the lake, excavation for increasing water volume of the lake, freeing lakes from land grabbers and for some of beautification features (The Independent, 2017). To purify the contaminated water in the lake, the Government have planned to established water treatment plants (The Independent, 2017). For the waste management, the Public Works Ministry has been set its own treatment plants in this area (The Independent, 2017). Rajdhani Unnayan Kortripokhho (RAJUK) has been engaged another project from the year 2019 to 2021 on the cleaning of the Hatirjheel Lake water of 55 crores of taka as well (The Independent, 2017).

2.16.1.6.4.4 Study Area - 4: Ramna Lake

Ramna Lake is a part of the Ramna Park which located in Ramna thana (Razzak et al., 2013). An area of 68.50 acres, Ramna Park (23P °P44′14.70″ N, 90P °P24′03.4″ E) is placed in central Dhaka (Rajia et al., 2015). Ramna Lake was made in 1949 and the area of the Lake is 8.76 acre. This lake is 812 m long and width varies from 9-94 m at some points (Razzak et al., 2013). Formally, the Public Works Department (PWD) owns the lake Ramna (Siddiqui and Islam, 2021). Under the Ministry of Housing and Public Works, this Lake is maintained by the Public Works Department (PWD) (Prothom Alo English, 2016). Development work has been going on for around two years at the lake inside the Ramna Park (Siddiqui and Islam, 2021).

2.16.1.6.4.5 Study Area - 5: Diabari Bottola Lake

This urban wetland has been managed by mainly RAJUK and did not hand over still now to the Dhaka City Corporation (DCC). Recently, DWASA proposed a new project named ‘Uttara Sanitation Improvement Project (USIP)’ by the Local Government to the Planning Commission in this area. This project will reduce the contamination status and enhance the sanitation facilities in this area as well. Total length of the lake at the point 10,11 and 12 are 8.5 km approximately, invert level -1.0 m, crest level 6,0 m, total depth of the lake is nearly 7.0 m. In the winter season, the depth of the water is nearly 3.0 m and in the rainy season is nearly 3.55 m. Average top width of the lake is 82.30 m (crest to crest) and bottom width is nearly 54.30 m. In the winter season, this urban wetland can store 15,37,650 m3 of water and 24,64,326 m3 of water approximately (Unpublished report from RAJUK, 2023).

2.16.1.6.4.6 Study area – 6: Ashulia Urban Wetland

There is little access to legal and institutional support in this area and almost lack of support from different organizations are noticed. Union Parishad (UP) as Local Organization is the local administrative body and people have access to the elected Chairman and members of the committee. Under the different ministries, a number of sectoral agencies are responsible for this study area. Among different organizations, Paurashavas, Union Parishad, RAJUK, RHD, DWASA, BWDB, DoE, City Corporation, Bangladesh Environmental Lawyers Association (BELA), Bangladesh Poribesh Andolon (BAPA) etc. are responsible for the area (Islam, 2009).

2.16.1.6.4.7 Study area – 7: Birulia Urban Wetland

Information has not been available on this urban wetland.

Analytical Framework - 2: Urban Wetland Sustainability Framework (UWSF) Model - 2
External factors influencing the variation of average Dissolved Oxygen (DO) concentration across urban wetlands

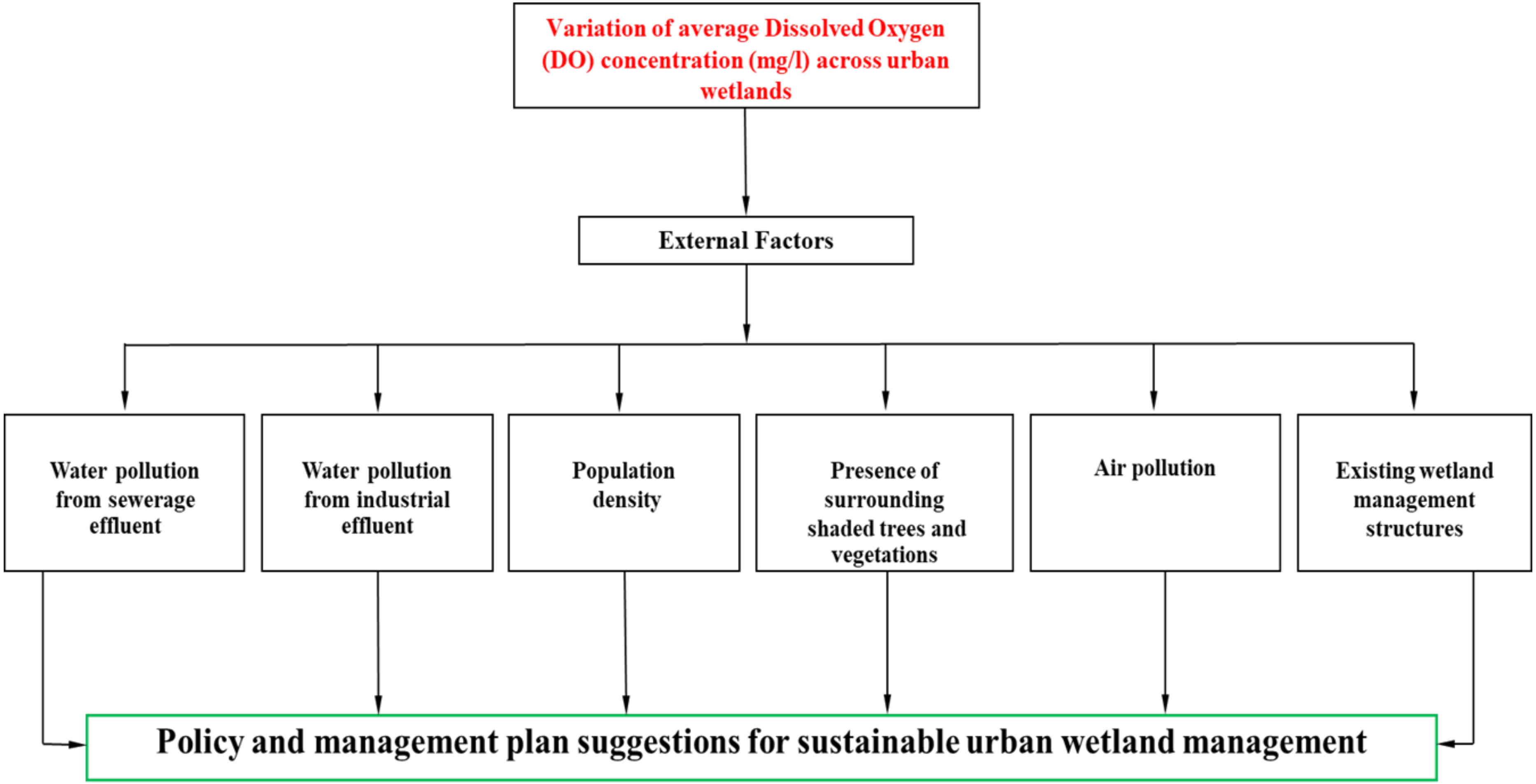

Figure – 2.5: Analytical Framework - 2 of the Research

2.17 Concluding Remarks

This chapter discussed the conceptual overview, urban wetlands in global and Dhaka city context, relevant policies and institutions connecting urban wetland management in Bangladesh and Analytical Framework - 1 and 2.

CHAPTER - III

METHODOLOGY AND STUDY AREA

This chapter describes the methodology and study area of this research. The methodology of this research has been followed the objectives of the study. The main tenets of the methodology are as follows:

3.1 Research Methodology

The section begins with a discussion of the research design employed in the research and follows to discuss mainly the qualitative research designs. The present research is mainly based on qualitative approach. According to (Guba & Lincoln, 1994, p. 15)… 'Qualitative research is an interpretive and naturalistic approach' (Guba & Lincoln, 1994, p. 15). According to (Guba, 1990; Guba & Lincoln, 1994; Newman, 1994)… 'Qualitative research is based upon the observations and interpretations of people's perceptions of different events' (Guba, 1990; Guba & Lincoln, 1994; Newman, 1994). The further steps followed in this section are stated as below:

3.1.1 Phase of Data Collection

This research has been conducted both primary and secondary data from different sources.

3.1.1.1 Primary Data

Primary data has been collected through semi-structured questionnaire survey of study areas stakeholder perceptions, semi-structured interview with institutional stakeholder expert's perceptions, author perceptions by personal field observation, the water quality assessment through different methods in Department of Environment (DoE) and investigating the external factors and how these factors are influencing the variation of average Dissolved Oxygen (DO) concentration across selected urban wetlands by author personal field observation.

3.1.1.1.1 Semi-structured Questionnaire Survey with the Study Area Respondents

A semi-structured questionnaire survey was conducted in selected study areas face-to-face with local peoples as stakeholders. Sites were visited thirty days within six months of period and data collected from year 2018 to 2021. During this survey, five attributes of sustainability have been selected that followed from IUCN Integrated Wetland Assessment Toolkit (detail in Chapter - II) for urban wetland management. These attributes have been taken on the perspective of Bangladesh (with modified attributes) to identify relevant information from different case studies in Dhaka city. These five attributes are 'contribution for biodiversity conservation and enhancement', 'resilience of urban water body to face the challenge of climate change impacts', 'contribution for community livelihood', 'adequacy of the policy regime', 'local acceptance and credibility of the role of relevant institutions' etc. A five-point Likert scale has been used to capture study area stakeholders' perceptions and views according to five selected attributes in the study areas. These scales are very effective contribution, effective contribution, moderately effective contribution, less effective contribution and not effective at all. These attributes of sustainability have been investigated the current scenario, existing role and challenges of urban wetland management and use according to study area stakeholders' perceptions in the selected study areas with the application of 'Urban Wetland Sustainability Framework (UWSF) Model -1' (detail in Chapter - II) and (Table – 3.1). For the interview, thirty numbers of stakeholders as purposive samples from each study area have been selected and a semi-structured questionnaire has been used to collect required information from these stakeholder's perceptions (detail in Appendix - 1 - [A]). Different mixed status of study area stakeholders as vendors/hawkers, small shops owner for tea, cigarette, cake etc., water transport staff, respondent on nursery activities, respondent on easy bike activities, respondent on horse cart activity, small restaurant staff, mobile small restaurant staff, big permanent restaurant staff, amechar fishermen, fish farmers, agricultural farmer, daily labor for agricultural activities, poultry farmer, labor for brick manufacturing work, boatmen, security guards, cleaning staff, neighborhood people, local people, visitors etc. have been selected for the study area stakeholders (detail in Appendix - 2).

3.1.1.1.2 Semi-structured Interview with the Institutional Stakeholder Experts

Semi-structured interview with the stakeholder experts of different organizations and institutions have been conducted with total thirteen no. purposive samples as RAJUK (Urban Planner), PWD (Sub-Assistant Engineer), DoE (Deputy Director), DSCC (Executive Engineer), DWASA (Executive Engineer), BFDC (Senior Manager), POBA (Chairman), Up (for Ashulia) (Secretary, Member), Up (for Birulia) (Secretary, Member), University Teacher (Water Resource Scientist, BUET/BRAC University), IWFM (Director, Hydro Geologist), IUCN (Country Representative), Vitti Thapotto Brindo (Architect) etc. with their perceptions and views on current scenario, existing role and challenges of selected urban wetland management and use with the application of 'Urban Wetland Sustainability Framework (UWSF) Model -1' (detail in Chapter - II) and (Table – 3.1). In this regard, a semi-structured questionnaire and five-point Likert scale has been used to collect required information from these stakeholder's perceptions as well (detail in Appendix - 1 - [B]). During the thesis preparation, this information helped to conceptualize and formulate the thesis plan and suggest the recommendations.

3.1.1.1.3 Personal Field Observation

Field observation by the author has been done for investigation of current scenario, existing role and challenges of selected urban wetland management and use with the application of 'Urban Wetland Sustainability Framework (UWSF) Model -1' (Table – 3.1). Along with observation method, photographs have been taken to demonstrate the existing status and challenges of selected study areas.

Table – 3.1: Application of 'Urban Wetland Sustainability Framework (UWSF) Model – 1' according to the selected study area stakeholders' perceptions, institutional stakeholder experts' perceptions and author personal field observation

Urban Wetland Sustainability Framework (UWSF) Model -1	Current scenario, existing role and challenges of selected urban wetland management and use		
	Selected study area stakeholders' perceptions	**Institutional stakeholder experts' perceptions**	**Author personal field observation**
(1) Contribution for biodiversity conservation and enhancement			
(2) Resilience of urban water bodies to face the challenge of climate change impacts			
(3) Contribution for community livelihood			
(4) Adequacy of the policy regime			
(5) Local acceptance and credibility of the role of relevant institutions			

3.1.1.1.4 Water Quality Assessment in Study Areas

Water quality assessment has been conducted to test of ten parameters in selected study areas. These parameters have been tested through different methods in Department of Environment (DoE) Laboratory with the laboratory technicians (samples collected by the author at three feet below from surface level of water bodies) during the month of October, November and December in the year 2020 to investigate the quality of water either it's suitable for aquatic biodiversity conservation or not.

3.1.1.1.4.1 Selection of Sampling Locations in Study Areas

The water samples were collected from two sampling locations for each study area and per month (Table – 3.2), (Appendix – 3: Table – 4 and 5; Figure – 01, 02, 03, 04, 05, 06, 07). Sampling locations have been selected according to most human interference areas and much pollution areas by the author field observation.

Table – 3.2: Water sampling locations in selected urban wetlands

SL. no.	Water samples	Sampling Locations
01.	S - 01	
02.	S - 02	

3.1.1.1.4.2 Selected Water Quality Parameters from Study Areas

Total forty-two (42) no. samples of water (500 ml) have been collected from selected study areas (two samples from each study area and per month) that covering the month of October, November and December 2020 and tested in the Department of Environment (DoE) laboratory. For assessment and monitoring the water quality of selected urban wetland, total ten (10) nos. water parameters such as Temperature, pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Turbidity, Nitrate-Nitrogen (NO3-N), Phosphate (PO4), Total Dissolved Solid (TDS) and Electrical Conductivity (EC) etc. were examined for each sample to monitor the level of these parameters whether it exceed or within the permissible limit of Environmental Quality Standard (EQS) that has been followed by the Department of Environment (DoE).

3.1.1.1.4.3 Analytical Methods Used for Determination of Water Quality Parameter

In this research, different analytical methods used for determination of water quality parameters according to the Department of Environment (DoE) for different samples that shown in the (Table – 3.3):

Table – 3.3: Analytical methods used for determination of water quality assessment according to the Department of Environment (DoE) Laboratory

SL. No.	Water Quality Parameter	Unit	Methods Used in the (DoE) Laboratory
1	Temperature	oC	Thermometer
2	pH	-	Standard Method/Using Electrode
3	DO	mg/L	Modified Winkler's Method/Titrimetric Method
4	BOD_5	mg/L	Dilution Method
5	COD	mg/L	Closed Reflux Colorimetric Method
6	Turbidity	NTU	Nephelometric Method
7	Nitrate-Nitrogen (NO_3-N)	mg/L	UV - Visible Spectrophotometer (UVS)
8	Phosphate (PO_4)	mg/L	UV - Visible Spectrophotometer (UVS)
9	TDS	mg/L	Gravimetric Method
10	EC	(umohos/cm)	Standard Method

3.1.1.1.5 Investigating the External Factors and how these Factors are Influencing the Variation of Dissolved Oxygen (DO) Concentration in Selected Urban Wetlands

In this research, ‘Urban Wetland Sustainability Framework (UWSF) Model – 2’ has been chosen that will provide the basis for investigating the external factors and how these factors are influencing the variation of average Dissolved Oxygen (DO) concentration across selected urban wetlands by author personal field observation. Total six external factors have been selected as water pollution from sewerage effluent, water pollution from industrial effluent, population density, presence of surrounding shaded trees and vegetations, air pollution and existing wetland management structures etc. have been described in detail in Chapter - II. To what extent these external factors are affecting the average DO level of water, we have divided the level of influence into three categories as low (1), medium (2) and high (3) for the analysis.

3.1.1.2 Secondary Data

Secondary data sources played a significant role to have a comprehensive idea about the urban wetland issues. Secondary data has been collected through following aspects:

3.1.1.2.1 Conceptualization and Review of Literature

This chapter provides the theoretical background, including detailed discussion on urban wetland-based information as different concepts covering current status, existing role and challenges of urban wetland management and use on the global and Dhaka city context; discussion on the existing urban wetland management structures covering the policies, acts, regulations etc. and institutions, organizations etc. on the context of Dhaka city; review of the literature on existing urban wetland management structures on the context of study areas; detail discussion on the analytical frameworks with the application of ‘Urban Wetland Sustainability Framework (UWSF) Model -1 and 2’; review of the literature covering different urban wetland case studies with the application of ‘Urban Wetland Sustainability Framework (UWSF) Model -1’ on the global and Dhaka city context; discussion on the location of selected study area etc.

3.1.1.2.2 Literature Related Documents

Secondary data collected through different books, journals, articles, papers and newspapers etc. Following (Figure – 3.1) shows the flow diagrams of research phases and method of data collection.

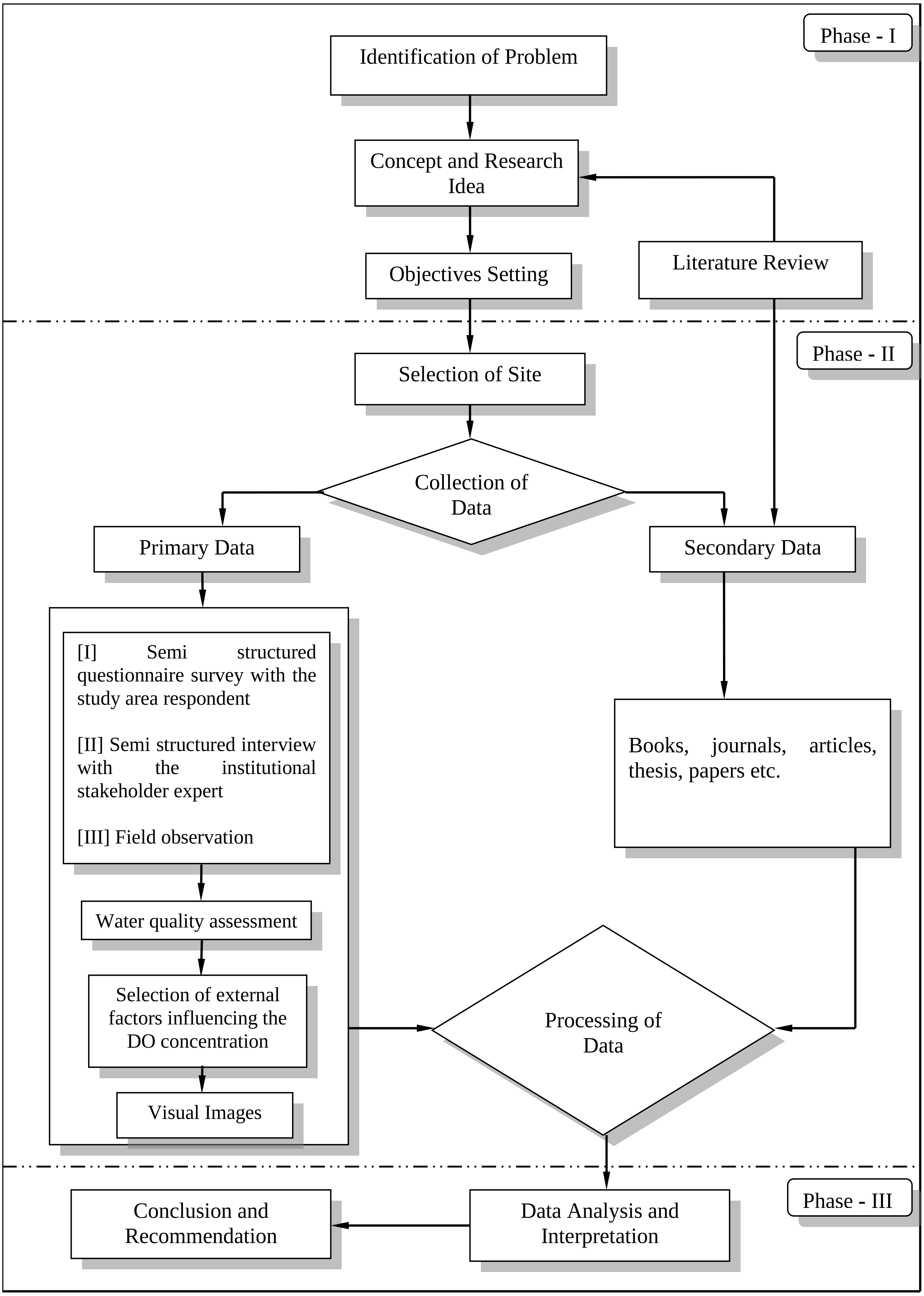

Figure – 3.1: Flow Diagrams of Research Phases and Method of Data Collection

3.2 Study Area

The study area that had chosen that will represent the basic and typical characteristics of the whole structure of this study. Study area was taken according to the characteristics and types of urban wetland criteria and where there is availability of urban wetland within and adjacent to Dhaka city. Considering above criteria, total seven study areas within and near to capital city of Dhaka are selected for this study. These are Study area - 1: Dhanmondi Lake, Study area - 2: Gulshan-Baridhara Lake, Study area - 3: Hatirjheel Lake, Study area - 4: Ramna Lake, Study area - 5: Diabari Bottola Lake, Study area - 6: Ashulia urban wetland and Study area - 7: Birulia urban wetland (Appendix – 4: Figure – 08 and 09).

3.2.1 Rationale for Study Area Selection

Among selected study areas, Study area – 1, 2, 3, 4 and 5 have been selected on the definition of Ramsar urban wetlands criteria as urban water bodies that are urban lake. Study area – 6 and 7 have been selected for urban wetlands that are river flood plain. Selected urban wetlands in Dhaka city are not only important for the sustenance of the aquatic eco-system, but also considered as main source of direct and indirect role of urban wetland. Maximum of these water bodies are unsustainable in the capital and have been degrading recently. These wetlands have been suffering from highly significant pollution in recent days for the economic development, unplanned urban expansion, higher population growth, climate change and other reasons. During the dry season the pollution becomes worst as the level of water goes almost down. Lack of proper maintenance of existing drainage system results random drainage outlets which dispose untreated domestic, municipal, commercial, industrial and other toxic waste and wastewater in the city water courses. The overall quality of these urban water courses declining at present for the lack of management and other reasons. So, it is urgent need to protect, conserve and manage these fresh water bodies as soon as possible with the sustainable point of view. Under these circumstances, considering all the constraints and challenges, these urban water bodies were selected and articulated as study areas in this present research to offer a better sustainable management concept in near future.

3.2.2 Study area - 1: Dhanmondi Lake

In Dhanmondi area, maximum places are surrounded by green. Its lakeside development turned itself as the most successful recreational space for Dhaka city. Its Parks and water body redevelopment projects (Dhanmondi lakeside conservation), designed structures like amphitheater, colonnades, pavilions etc. (Rabindra Sarabar, Bachelor's point etc.), recreation centers (Dingi, Sampan, Panshi etc. waterfront restaurants) are in the center of green city development initiatives (Afrin et al., 2014).

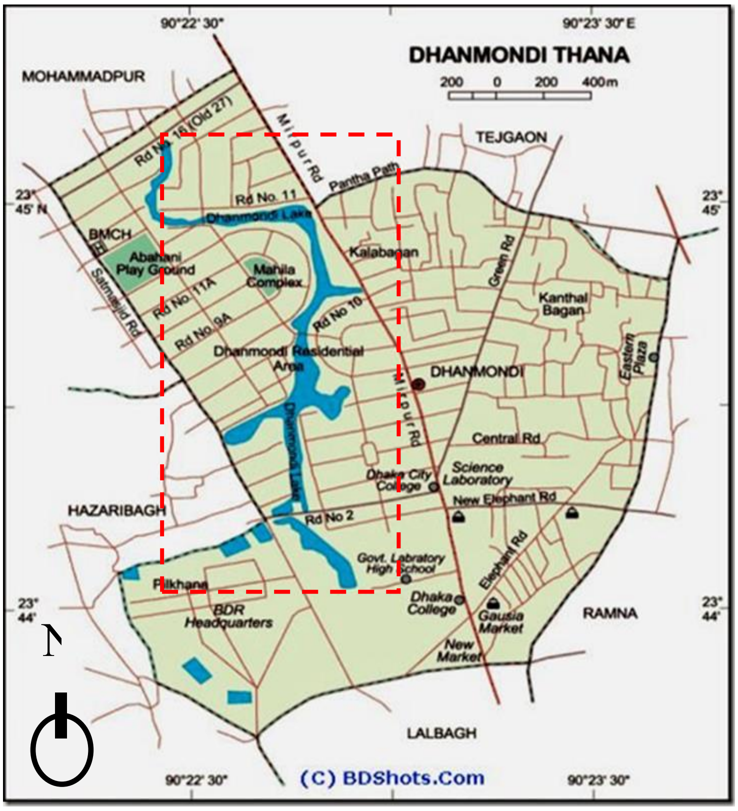

Figure – 3.2: The location map of Dhanmondi Lake [Source: (Google Image, 2018)]

In Dhanmondi area, Dhanmondi Lake is situated 23°43'N latitude and 90°26'E longitude in the middle of Dhaka city. Dhanmondi Lake is starting from Jigatola and spreads up to Road nos.-27, bounded by the Mohammadpur-Lalmatia area in the north, Bangladesh Rifles Gate in the south, Kalabagan residential area in the east and in the west of Satmasjid Road (Razzak et al., 2012). This Lake is 3 km in length, width varies from 35 m to 100 m with a maximum depth of 4.77 m and the total area of the water body is approximately 37.37 ha. There is one box culvert in the lake near Sukrabad area, which is the only outlet of the lake (Razzak et al., 2012) (Figure – 3.2).

3.2.3 Study area - 2: Gulshan-Baridhara Lake

Gulshan area was developed as a planned residential area which is now later turned into a commercial zone and almost covered by a green belt (Afrin et al., 2014). Even though, the Gulshan Park and Lake have amazing green beautification and it endows with vast gathering of mass people often (Afrin et al., 2014). Gulshan-Baridhara Lake is the northernmost lake in a chain of water bodies (Gulshan Lake, Hatirjheel, Begunbari Khal, Balu River and Shitalakhya River) in Dhaka, suffering from highly significant pollution. This lake is located 23°48' N and 90°25' E of Dhaka city. The length of the Gulshan Lake is 3.8 km that covers an area of 0.0160 km2 (Nishat, 2000). It has an average depth 2.5 m and volume 12 x 105m3 (Nishat, 2000).

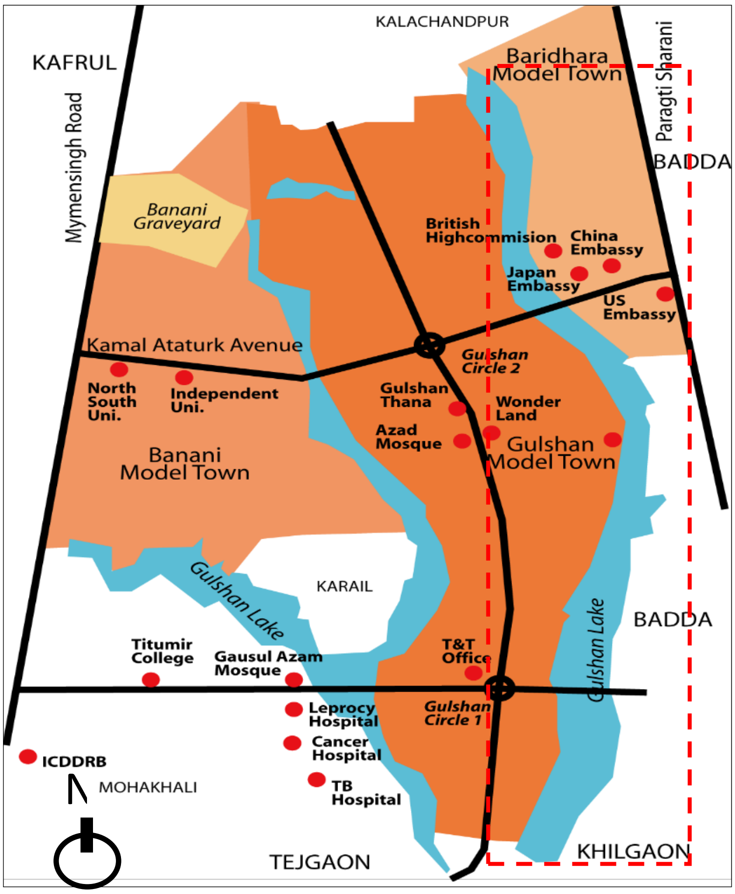

Figure – 3.3: The location map of Gulshan-Baridhara Lake [Source: (Google Image, 2018)]

Both Gulshan and Banani Lakes provide the role of retention ponds as well (Sultana and Chowdhury, 2013). The combined area of the Gulshan-Baridhara and Banani Lake is about 200 acres of which 60% is contained by the Gulshan-Baridhara Lake. Width of the lake is 600ft (approx.) along the link road between Gulshan circle-1 and Baddah (Sultana and Chowdhury, 2013). The lake is a channel-like elongated water body (F. A. Mohuya, 2010) (Razzak et al., 2013). This Lake was declared an Ecologically Critical Area (ECA) in 2001 to save the water body from becoming further polluted and to protect it from encroachment (F. A. Mohuya, 2010) (Razzak et al., 2013) (Figure – 3.3).

3.2.4 Study area - 3: Hatirjheel Lake

The Hatirjheel Lake or the "Lake of Elephants" is the city's largest reservoir which was literally a place where the royal elephants were taken for their daily bath during the Mughal reign (Sultana and Hafiz, 2013). It is located in the center of Dhaka and is a crucial element in the city's drainage system (Peeters and Shannon, 2009). Hatirjheel Lake stretches from the eastern side of the Tongi diversion road to the Rampura Bridge on Pragatisarani including the low-lying area behind Sonargaon hotel (beyondbuildingbd.com, 2013). It used to be connected to a string of other lakes, the Banani, Dhanmondi and Gulshan Lakes and to the Begunbari Khal at the Rampura Bridge. The Begunbari Khal used to be a very important waterway during the Mughal period (1608-1764) and functioned as the entry to the city (Ferdous and Nilufar, 2007, p. 55).

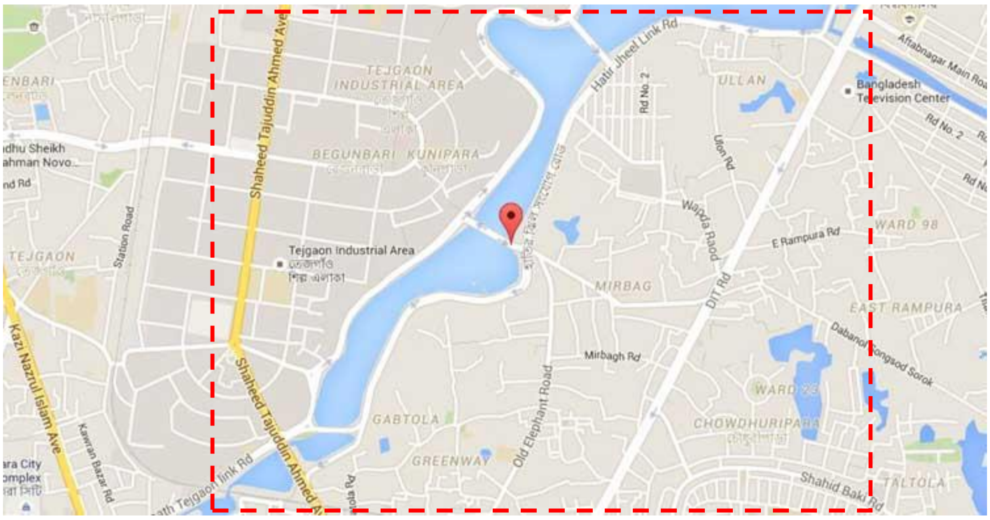

Figure – 3.4: The location map of Hatirjheel Lake [Source: (Google Image, 2018)]

However, in (1991), the canal was turned into a box culvert with an arterial road on top of it, named Pantha Path, following the demand for better accessibility through the very dense urban tissue and the unattractive condition of the water. At Rampura Bridge, which is part of a temporary embankment, there is a pumping station with a sluice. This prevents backflow from the Balu River in the east in case it bursts its banks. Hatirjheel Lake is the reservoir of one third of the catchment area of the city (MacDonald and Culpin, 1995) and there is a high variation in its water level between the dry and wet seasons (from May to October), with a normal flood-level of 4.6 meters and a water level at 6 meters or more during extreme rainfall (MacDonald and Culpin, 1995) (Peeters and Shannon, 2009) (Figure – 3.4).

3.2.5 Study area - 4: Ramna Lake

Ramna Lake is situated in Ramna thana and it is a part of the Ramna Park. The area of Ramna Lake is 8.76 acre (Razzak et al., 2013) (cited in Islam et al., 2015). Its width varies from 9-94 m to some points and the lake is 812 m long (Razzak et al., 2013) (cited in Islam et al., 2015). Ramna Lake is situated in the middle of Dhaka city (Sarkar et al., 2019). It also lies within the vicinity of Shahbag areas. The lake is about 8.76 acres (Sarkar et al., 2019) (Figure – 3.5).

Figure – 3.5: The location map of Ramna Lake [Source: (Google Image, 2018)]

3.2.6 Study area - 5: Diabari Bottola Lake

Diabari Bottola Lake is a picturesque natural attraction located in Uttara, Bangladesh. With its serene and tranquil ambiance, the lake offers a refreshing getaway from the bustling city life. The surrounding greenery and the clear waters make it an ideal spot for nature lovers (Islam, 2023). Visitors can enjoy boating and fishing activities, adding to the overall charm of the place (Islam, 2023) (Figure – 3.6).

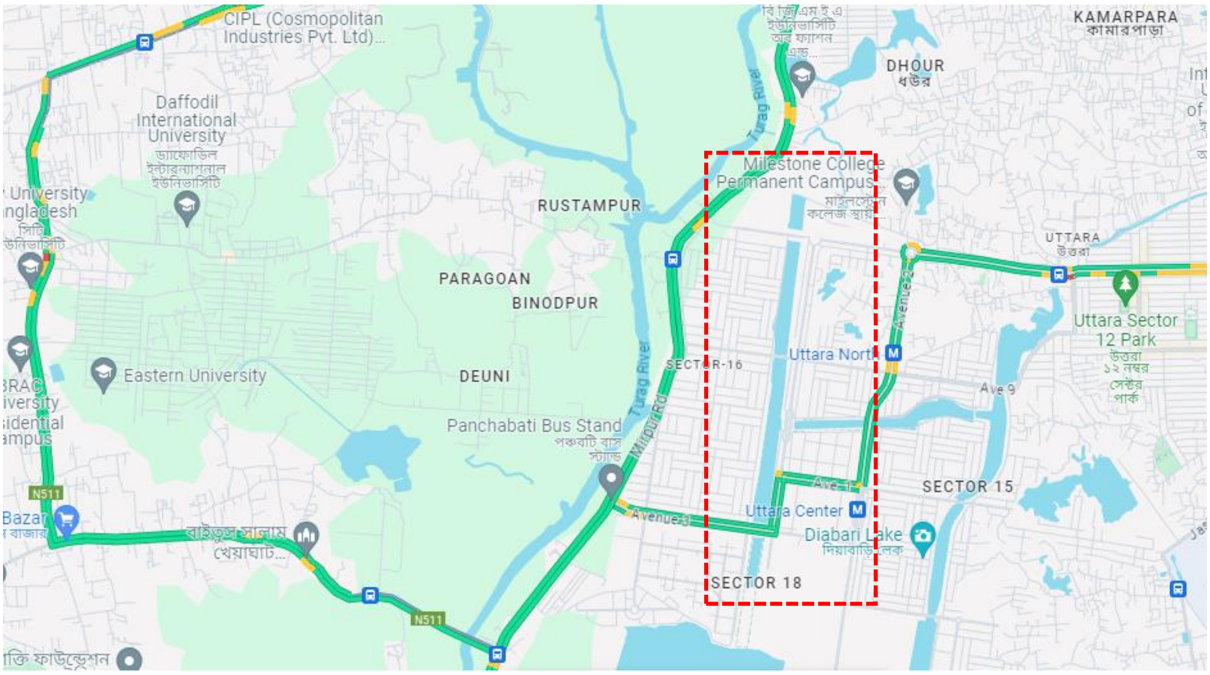

Figure – 3.6: The location map of Diabari Bottola Lake [Source: (Google Image, 2018)]

3.2.7 Study area - 6: Ashulia Urban Wetland

Ashulia basically is a sub-urban area. The area where this water body play a vital role as catchment areas in facilitating the drainage of water from Dhaka city in the wet season. The lowlands of Ashulia wetland serve as the withholding body for the surplus water of the Turag and Balu Rivers during rainy season as these rivers have no specific banks of their own. In the Dhaka Metropolitan Development Plan (1995-2015), Ashulia is demarcated as the main flood flow zone. Ashulia is not only playing a vital role as a wetland but also as a recreational spot (Begum, 2009).

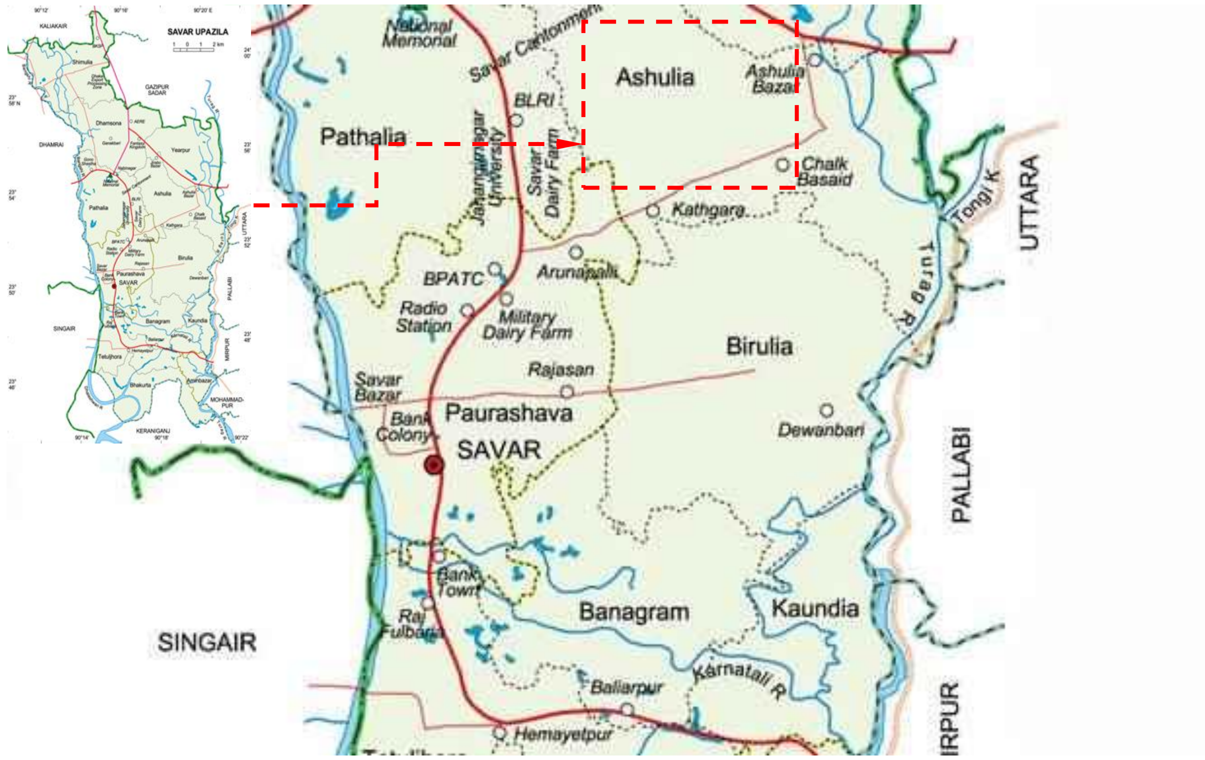

Figure – 3.7: The location map of Ashulia urban wetland [Source: (Google Image, 2018)]

Ashulia sub-urban water body is being used as a recreation point by the recreational users of Dhaka city. People are strolling, roaming, boating, gossiping and enjoying the scenic beauty of the river there. The attractive view of Turag River and vast paddy fields of Ashulia make it a popular tourist spot and is one of the nicest and most romantic places nearby Dhaka. People love to go there with their friends and families. Now-a-days Ashulia meet the demand of recreational site with boating and other facilities for the city dwellers. It is a nice place where one can get fresh air and also recreate. For its absolute natural beauty during monsoon, it is called the Cox's Bazar of Dhaka. Again, in winter it has another attraction for its cosmic greenery natural exquisiteness provided by paddy and vegetable fields (Sultana, 2012) (Figure – 3.7).

3.2.8 Study area - 7: Birulia Urban Wetland

The Birulia wetland is located (23°51'28.9"N 90°18'33.0"E) at Savar Upazilas of Dhaka district and about 25km from the center of Dhaka city on the Dhaka-Manikgonj highway (Sadat et al., 2020). Birulia is situated near Ashulia by the river Turag. This area is historically important due to a number of old buildings bearing high architectural and archeological value. Birulia was a business center and river port at that time. It’s not only a heritage site but also a natural setting of area which turns it into a picturesque island that surrounded by water during the monsoon (Islam and Adnan, 2017) (Figure – 3.8).

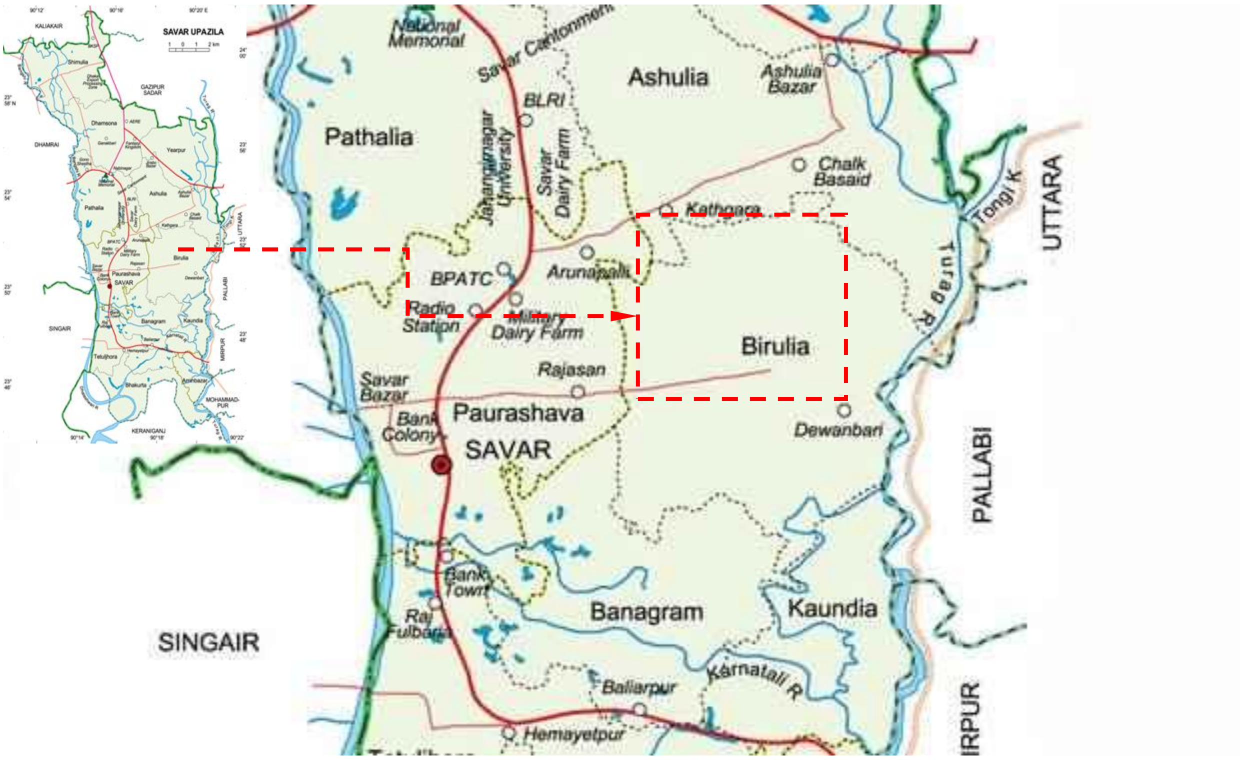

Figure – 3.8: The location map of Birulia urban wetland [Source: (Google Image, 2018)]

3.3 Concluding Remarks

This chapter discussed the research methodology, phase of data collection, study area and rationale for study area selection etc.

CHAPTER - IV

FINDING AND ANALYSIS – 1

This chapter discussed the current status, existing role and challenges on management and use of urban wetlands on the Global and Dhaka city context according to 'Urban Wetland Sustainability Framework (UWSF) Model – 1' that developed for the present research by following research objectives and research questions first and second.

4.1 Applicability of the Urban Wetland Sustainability Framework (UWSF) Model – 1 on the Global Context

This section describes the current status, existing role and challenges on management and use of urban wetlands on the Global context according to 'Urban Wetland Sustainability Framework (UWSF) Model – 1' for this research as following (Table – 4.1):

Table – 4.1: Current status, existing role and challenges on management and use of some urban wetlands case studies on Urban Wetlands according to the Urban Wetland Sustainability Framework (UWSF) Model – 1 on the Global Context

Case Studies	Attributes of Sustainability				
	Contribution for Biodiversity Conservation and Enhancement	**Resilience of Wetlands to Face the Challenge of Climate Change Impacts**	**Contribution for Community Livelihood**	**Adequacy of the Policy Regime**	**Local Acceptance & Credibility of the Role of Relevant Institutions**
Chilika Urban Wetland, Orissa, India	Chilika urban wetland is the largest wintering ground for migratory birds (hosts over 160 species of birds) on the Indian sub-continent and supports number of threatened species of plants as well as animals. Having its rich biodiversity with variety of birds, vertebrate, marine, brackish and freshwater species	This urban wetland is a natural brackish salt water lagoon of Bhubaneswar, Orissa, India located in South-East Asia whose water spread area varies between 116500 in monsoon to 90600 Hectors in pre-monsoon (Rout, 2006).	132 villages on the shore and islands are dependent (more than 0.2 million as fisher-folk and 0.8 million as watershed community) on fishery resources	-	The Chilika Lake was declared as a Ramsar site in 1981(P.K. Naik et al, 2008). Chilika Development Authority (CDA) is the central organization with Chief Minister as a

	as well as fisheries along with preserving genetic diversity, it was enlisted in Ramsar Convention for Wetland (Wikipedia, 2014; Rout, 2006). Issues like increase of siltation, degradation of the drainage basin, alteration of fresh water flow and decrease in salinity has resulted in shrinkage of water-spread area, loss of biodiversity and depletion of fishery resources raised due to different activities. Besides, the natural recruitment of species is adversely affected by the shoal formation and continuous shifting of the mouth of sea due to tidal influx into the lake. Therefore, loss of biodiversity takes place in the water body (Pattnaik, n.d.).		of Chilika Lake. Besides, this lake also contributes on Agriculture sector as it involves 77% of the working population from peripheral villages (Pattnaik, n.d.). International tourists and ecotourism are the other sectors that contribute to the local economy (Rout, 2006). Loss of biodiversity with productivity declination further adversely affected the livelihood of the community depending on it. Limited occupation opportunities and land holdings, existing conflict between fishermen and non-fishermen communities for fishing rights in		Chairperson, acting to integrate various organizations (11 international organization, 4 national ministries, 6 other national organizations, 17 state government organizations, 13 research institutes, 33 NGOs and Community Based Organizations and 5 Community groups (Pattnaik, n.d.). The common property resources of Chilika Lake are managed by all these organizations. Besides, legitimate stakeholders, (Local communities and Indigenous people) take active role in planning and restoration process (Rout, 2006). City Development Authority (CDA) implemented the

			the lake gradually led to poverty and migration (Pattnaik, n.d.).		ecosystem approach (through integration of local communities) to conserve this wetland. Besides, local NGOs developed community's capacity building to aware them about the ecological goods and services provided by the lake systems which contribute to their livelihood. Community participation sets up an example in *Dangei Pahad* micro watershed in degraded watershed areas where more than 3,000 villagers (including the women and children) participated and learned to use the watershed thoughtfully by

					planting more trees instead of cutting to conserve the watershed. Besides, lack of institutional mechanism to regulate the common resources resulted in unsustainable and unbalanced resource distribution and use (Pattnaik, n.d.).
Kankaria Urban Wetland, Ahmadabad, Gujarat, India	The Kankaria Lake created by Sultan Qutub-ud-din in 1451, is the biggest lake (25.17 hectors in area and 4.8 km in circumference) in Ahmadabad, Gujarat. Though this lake was created with water purifying system, it is lost in course of time and it is only significant for its historical and cultural values nowadays (Wikipedia, 2014). Besides, the lake is famous for attracting birdlife (Centre of science environment, Amandeep Kang, 2013).	The lake is facing various environmental issues and as a result it dried up (the water level reduced from 16-17 feet to 10-12 feet in depth) due to siltation (Ranade, 2008).	This lake performs recreational activities which attracts tourists of all age groups from home and abroad. It also holds social performance and congregation platform in events like Ras Garbha, Kankaria Carnival, Dog show by Police etc. (IDC, 2009).	-	As the lake is located in the heart of the city, the Gujarat Government took up the comprehensive lakefront precinct and appointed Ahmadabad Municipal Corporation (AMC) to develop it as a recreational urban space (IDC, 2009). Besides de-siltation and cleaning of the lake, AMC developed lake front facilities [Toy Train,

					Indoor sports Stadium, Laser show, Jogging Track, Aquarium, Zoo, Park (Nagina wadi), Amusement Park (Balwatika), Butterfly Park, Food Court, Lighting etc.] with a charge of Rs 10 as entry fee. The lake along with its garden also attract people for walking, relaxing, yoga and running (IDC, 2009).
Mansagar Urban Wetland, Jaipur, Rajasthan, India	Mansagar Lake or ‘Jalmahal’, is a manmade water body created by Raja Man Singh I in 1610 in the walled city of Jaipur, Rajasthan. The lake was created by damming the Darbhawati River near Nahargard Fort to support irrigation issues of the area. This lake (121.41 hectors) holds a palace in the middle and a temple on northwest which made it significant for recreational purpose (Paritos Gupta et al., 2008). Domestic	Extensive deforestation in the surrounding hills as well as the sewage (from Jaipur city) diverted into the lake recently caused rapid siltation which reduced water storage capacity of the lake. As a result, the palace submerges (three meter or more) during the rainy season (IDC, 2009).	The lake is located at the vicinity of Amber fort which made it an attractive tourist place for home and abroad. Besides, as it is the only water body in Jaipur, it is also used for vegetable cultivation and irrigation and	-	For the management and renovation of Mansagar Lake, Jalmahal Monument and Lake area on three major conservation project components, Government of Rajasthan, Jaipur Development Authority, Rajasthan Tourism Development and

	waste water is treated by Sole Sewage Treatment Plant (STP) which is insufficient. Besides, eutrophication limits the survival of the macrophytes. All these issues strongly affected the lake water and its biodiversity. Previously the lake hosts more than 150 species of migratory as well as resident birds which has reduced due to the decrease in forestland (flora and fauna) of the lake (IDC, 2009).		contributes in the livelihood development of the local people (IDC, 2009).		Corporation, Department of Tourism, Forest Department, Jalmahal Resorts Pvt. Ltd., Irrigation Department, Jaipur Municipal Corporation etc. are some of institutions (IDC, 2009). NLCP deals the lake conservation plan for the Mansagar Lake which includes the diversion and treatment of wastewater, de-siltation, bioremediation, afforestation and catchment treatment. Besides, proposals are under consideration (4 hectors of wetland construction) to maintain water level and improve the quality of water. The University of Rajasthan provides

					the baseline data upon which water quality is regularly monitored and to enhance the water treatment quality, existing STP is redesigned and renovated. Settling tank was constructed to trap the sediments from hills which were gradually dredged and were used to create few islands (planted to promote biodiversity of birds and encourage bird watching) which enhanced the aesthetic and educational value of the lake (Rana, 2008).
Hebbal Urban Wetland, Bangalore, India	Hebbal Lake (76.87 hectors) is located at the most elevated part of Bangalore surrounded with three major valleys and abutting ring road on south is the habitat for numerous local and migratory	-	This lake serves different purposes such as, pisciculture by the Fisheries Department,	-	To rejuvenate Hebbal Lake, Department of Forest, Ecology, Environment and Government of

	birds (Krishna, n.d.). As the lake is surrounded by building and industries, bathing, washing cloth, idol immersion etc. pollute the water along with the waste water from the storm water channels. Besides, agricultural fields in catchment areas of the lake provide toxic elements that causes water pollution due to which fishes and birds died (due to pollution and dehydration) resulting in ecological damage along with degradation in ground water quality (water unsuitable for drinking purposes) [VIMOS Technocrats and Associates (T.V. Ramachandra and V.G. Ranjani, 2000)].		agriculture in catchment areas, boating, livestock as well as domestic water use etc. [VIMOS Technocrats and Associates (T.V. Ramachandra and V.G. Ranjani, 2000)].		Karnataka formed Hebbal Lake Park Association (HELPA) in 2002 with the funding from the Indo-Norwegian Environment Program. The experts of the forest department provide lake cleaning, de-weeding, de-silting (by mechanical means using excavator), diversion of sewage etc. services for conservation and management of the Lake (S. Shivanand and D. Gandhi, 2007). Besides, construction of silt trap, providing sanitary facilities, STP, solid waste collection and disposal arrangement, awareness campaign,

					environment education, lake front development for recreation along with creation of islands with fruit bearing trees for birds are the other initiatives taken by the authority (VIMOS Technocrats and Associates, n.d.). Lake Development Authority (LDA), a single nonprofit society formed by the Government of Karnataka for regeneration and preservation of the lakes, leased out the lake to East India hotels Ltd. (Oberoi group, private company) in 2006 for lake conservation and development (Fernando, 2008).
Urban wetlands in	Most of the urban wetlands or lakes (locally known as "setu or	-	-	-	-

Jakarta	situ”) in megacity Jakarta are part of the watershed area of two main rivers named Ciliwung and Cisadane that flow across the interconnected regions with mixed urban or other types of watersheds (rural, industrial, agricultural etc.). Change in land use due to land expansion for housing, using as dumping grounds for garbage, collection of untreated sewer and storm water runoff, lack of public concern, lack of management of the government are some of the urban development issues which causes the recent damage of environmental conditions of these urban lakes. According to the studies area shrinkage, siltation/sedimentation, eutrophication and water pollution are the reasons behind the present conditions of urban lakes in megacity Jakarta, while in some lakes toxic cyanobacteria and metals contamination are the reasons (Hennya and Meutiab, 2013).				
Nakivubo Urban	According to NWCMP (1996), over one sixth of Kampala	-		-	-

Wetland, Kampala, Uganda	District (31 sq. km) is covered by wetlands, most of which flow towards Lake Victoria. Nakivubo wetland is the largest (5.29 sq. km with a total catchment area of 40 sq. km) of the twelve main wetland areas in Kampala (COWI/VKI, 1998). Located at the south-east of Kampala District, Nakivubo wetland forms a permanent swamp by the Nakivubo Rivers with its tributaries (the Katunga, Kitante, Lugogo and Nakulabye Rivers). Nakivubo became intensely degraded over recent years as this wetland runs from the central industrial district of Kampala (entering Lake Victoria at Murchison Bay) and passes through dense residential settlements along with commercial areas which is a major threat due to spread of industrial and residential developments (Emerton, Iyango, Luwum and Malinga, 1999). The wetland Nakivubo along with its surrounding areas are prime sites for urban expansion. Besides, settlement, industry as well as small-scale cultivation on its				

	fertile fringes encroached this wetland (COWI/VKI, 1998; Tumusiime and Mijumbi, 1999) and modified or reclaimed for agriculture, industry and settlement (Emerton, Iyango, Luwum and Malinga, 1999).				
Urban wetland in Australia	Australia is one of the most urbanized countries in the world with 89% of its population living in cities, towns and urban centers. This places pressure on the natural environment, including on wetlands that are within or close to urban centers. Many wetlands in Australia remain dry for years at a time (environment.gov.au/wetlands).	According to (environment.gov.au/wetlands), 'Urban wetlands in Australia provide a variety of benefits and services to the community. These wetlands provide habitat for plants and animals, water quality improvement function, can store water and can reduce of pollution etc. Wetlands also protect against natural hazards, slowing floodwaters, reducing the risk of fire and protecting against erosion of river banks and coastlines' (environment.gov.au/wetlands). Wetlands and associated vegetation can provide a cooling effect to surrounding areas in summer and also moderate strong winds (environment.gov. au/wetlands).	Urban wetlands can also contribute to the well-being of the community by acting as urban green spaces which provide aesthetic appeal, landscape diversity and recreational opportunities. Additionally, wetlands provide easily accessible educational opportunities to learn about the environment **(**environment.gov. au/wetlands).	**-**	Australia is a signatory to the Convention on Wetlands of International Importance (Ramsar Convention), which promotes the conservation and wise use of all wetlands. At the eleventh meeting of the Ramsar Convention, in July 2012, Australia and other member countries agreed to a set of principles for the planning and management of urban and peri-urban wetlands. This fact sheet provides guidance on how

					these principles can be applied in Australia **(**environment.gov. au/wetlands).
Victoria Basin urban wetland, Kenya	From the several rivers and drainages, the vast rooted and floating fringing wetlands of the lake provides a serious role of controlling and safeguarding the nutrient and contaminant loaded inflows entering into it, a function continuing to make the lake waters valuable for various uses, and supports the rich biodiversity (Kansiime, et al., 2007) (Okeyo-Owuor et al., 2012). Most wetlands bordering Lake Victoria are dominated by *Cyperus papyrus* L. or *Miscanthidium violaceum* (Kansiime et al., 2007). Papyrus wetlands are the most dominant in the Lake Victoria Basin and the inshore areas of the lake (Okeyo-Owuor et al., 2012).	Lake Victoria Basin moderate and influence the climate and the equatorial weather of the East African region (LVEMP, 2005; Swenson and Wahr, 2009) (Okeyo-Owuor et al., 2012). According to (Okungu et al., 2005), the equatorial location of the lake drives the process that defines the weather or meteorological characteristics of the entire basin and its neighborhoods (LVEMP, 2005; Swenson and Wahr, 2009). (Okeyo-Owuor et al., 2012).	To the East African community, the Lake Victoria Basin at Kenya, is a unique area especially due to its environmental, cultural, scientific, socio-economic, immense natural resources and huge investment potential. Water, biodiversity, fishery, wildlife, forests, land, minerals, multimodal transport, tourism etc. are some of rich properties in Lake Victoria Basin (EAC, 2004; LVBC, 2007 and LVFO	**-**	**-**

			2006 & 2007, Kisumu, 2007). The lake's fresh water and energy also provide great potentials for enhanced agriculture, trade and industry. By the Summit of the EAC, the Lake Victoria Basin has been designated as an economic growth zone (EAC, 1997). This lake is the largest inland water fishing sanctuary in the area of total harvestable fish species among 7,00,000 MT to 10,00,000 MT and yearly income estimated at US$ 500 million or nearly US$ 1.4 million/day, which mostly come from Nile Perch fishery (Mkumbo et al.,		

			2005). This sector employs over 3 million people with over 10 million dependents. The lake's full potential can still be enhanced to treble the current value through using efficient and sustainable methods of fishing (LVFO, 2007). The lake is also valuable for its wetlands resources that are major sources of livelihoods for riparian societies (Okeyo-Owuor et al., 2012). On its own, the lake basin is rich in natural resources. For instance, the wildlife which characterizes the Masaai Mara and Serengeti National		

			Parks present a characteristic phenomenon of high populations and diverse animal species. Values from these two parks are annually US$ 12 million from the income of wildlife driven tourism activities (UNEP, 2006). High valuable minerals such as gold, diamonds etc. and substantial natural forests are found in the basin as well (Okeyo-Owuor et al., 2012). In addition, the good fertile soils combined with high rainfall in the entire basin, makes the basin a high potential area for agriculture. For hydroelectric power generation,		

			this basin is also a natural water reservoir (Okeyo-Owuor et al., 2012). Further, the lake and the extensive river networks in its basin remain the most reliable source of drinking and industrial water for the populations living in rural areas, most major cities and towns in the basin. Lake Victoria wetlands constitute a vital life support system for about 12 million people who extract fresh water, fish, medicinal plants and building materials. Because of their ecological significance and importance to the livelihood of the		

			local populations, wetlands of Lake Victoria need to be conserved and managed in a sustainable manner. Due to limited knowledge of wetland ecosystems and little indebtedness of their function for supporting sustainable development and improving poverty, the socio-economic possibilities of Victoria Lake Basin has not been completely exploited (Okeyo-Owuor et al., 2012).		

4.2 Applicability of the Urban Wetland Sustainability Framework (UWSF) Model – 1 on the Dhaka City Context

This section describes the current status, existing role and challenges on management and use of some urban wetlands that have been selected as study areas on the context of Dhaka city according to 'Urban Wetland Sustainability Framework (UWSF) Model – 1' for this research as following (Table – 4.2):

Table – 4.2: Current status, existing role and challenges on management and use of some urban wetlands that have been selected as study areas according to the Urban Wetland Sustainability Framework (UWSF) Model – 1 on the Dhaka City Context

Selected Study Areas	**Attributes of Sustainability**				
	Contribution for Biodiversity Conservation and Enhancement	**Resilience of Urban Wetlands to face the Challenge of Climate Change Impacts**	**Contribution for Community Livelihood**	**Adequacy of the Policy Regime**	**Local Acceptance and Credibility of the Role of Relevant Institution**
Dhanmondi Lake	Dhanmondi residential area was developed around a lake (Dhanmondi Lake) which was then a natural drainage line in early sixties (Sultana, 2005). This narrow, man-made lake was originally a navigational channel connected to the surrounding river system (Japan International Cooperation Agency, 1987, Hossain et al., 2009, Khan and Rahman, 2010). For beautification	Climate change is one of the major threats for freshwater biodiversity in developing countries (Gopal et al., 2010; Woodward et al., 2010; Chowdhury et al., 2015). Study reveals that, Dhanmondi Lake has the lowest temperature difference with the regional temperature. Study also indicates, the presence of large amount of vegetation, less hard paved areas and also	The park along with the lake have also vision to restore the environmental quality enhancement for public facilities. Thousands of people of different ages visit the lake every day, most of them walk along the walkways to breath fresh air around the lake as well as exercise individually or in groups (Razzak et al., 2012). Different	Not Available	In 1996, after the inauguration of the museum "Bangabandhu Smriti Angan", Dhanmondi Lake development initiative was first taken by the then government to create parking facilities and accessibility of the increased public which included only the lake side area and the road 32. Gradually the government included the whole lake side area in the development project which comprises of the reshaping of the lake, lake side landscaping as well as the adjacent streets and walkways which eventually became a

	of the area, the lake was dug out and deepened within an area of 550 acres of land along with tree plantation around it (Sultana, 2005). Later, a walkway was built adjoining the bank to protect it from encroachment (Shahabuddin et al., 2012). Dhanmondi Lake has the highest level of vegetation and shading trees around it (Shahjahan and Ahmed, 2016) and enriched with Flora (Herbs, shrubs and trees) which is important to terrestrial ecosystems as animals depend on them in terms of food and shelter (Gorucu, 1997; Islam, 2015). Though species diversity in vegetation (Grass, Krishnochura, Neem, Lemon, Mango, Jackfruit etc.) is available in the lake surrounding, development works affected on the floral	the shape complexity are the several reasons behind the lower temperature difference (Shahjahan and Ahmed, 2016). During monsoon season (May-October), Dhanmondi lake area experiences intense water logging problem due to capacity failure of the lake when heavy rainfall occurs. Unplanned growth and development, poor infrastructures and systems (sewer and storm drains, solid waste collection and disposal) directly contribute to water logging problem this area. Moreover, substantially inadequate existing drainage infrastructures fail to accommodate overland flow generated by a typical storm and resulted water logging problem	people from diverse occupation such as various kinds of vendors, workers in tiny shops and restaurants etc. earn their livelihood from this lake (Sultana, 2012).		prominent public waterfront with its attractive panoramic views. As a result, many cultural centers, art galleries and music schools sprung out within the area (Alam, 2015). To create a pollution-free recreation zone, renovation was further carried out from 1998 to 2001 in and around the lake. In that time sources of pollution were identified as, municipal waste water and effluents from adjacent industries, tanneries, hospitals, pathology centres, garbage from restaurants and homes along with the hanging toilets of the floating population around the lake (Chowdhury, 2003b). Dhanmondi Lake is managed by several authorities for its various aspects. Ministry of Works has its ownership; Fisheries Department looks after its fishery; The Department of Environment looks after the aspects of proper environment and protection of aquatic resources and Dhaka City Corporation as the principal civic body performs some responsibility in its improvement

	biodiversity of the lake (Islam, 2015). The lake is an asset with unique regional characteristics for its neighborhood as well as for the whole city with its aesthetic, economic and environmental value. During extreme dry season, the lake retains considerable amount of water for fisheries as well as provides a habitat for a wide variety of aquatic vegetation and birds. In the past, the different parts of the lake have been drained through engineering interventions and turned into land for meeting growing housing and transportation demand of the neighborhood. The adverse effects of those interventions destroyed the fish and aquatic vegetables that flourish in the lake as well as blocked the natural flow of water which further	(Razzak et al., 2012). A study (Sharmeen, 2014) investigated that, Dhanmondi lake has a direct relationship with its surrounding urban environment in terms of relative humidity and air temperature up to a distance of 200m on the comfort conditions of this neighborhood. A significant difference in temperature and humidity was observed from the weather data and the field data (micro climate) due to the presence of this water body.			(Razzak et al., 2012; Islam, 2015). “Dhanmondi Lake and Lakeside Area Development Project” was initiated by Dhaka City Corporation (DCC) under the ministry of LGRD. The project stretches within an area of 85.60 acres (31 acres as land area and the rest 54.6 acres as water body). The vision of the project was to restore the environmental quality with enhancement of public facility. For proper administration, the project area was demarcated into 7 physical sectors each with a stretch of land that includes the newly developed facilities. Based on a two-tier management body for the operation and maintenance of the whole project, the administration comprised with the Advisory Committee [representatives from government (LGRD), project implementation authority (DCC), other related authority (WASA, LGED), local community and Bangabandhu Smrity Museum who will review, guide and instruct the management body and the

	affected the adjacent environment (Razzak et al., 2012). Besides, different natural processes as groundwater recharge, maintenance of aquatic life and ecological balance and recreational places in the lake all are affected (Nalepa et al. 1991, Vaughn and Hakenkamp, 2001, Vaughn et al., 2008). One study conducted in Dhanmondi Lake during the year 2010 which collected different additional environmental data during field survey (Japan International Cooperation Agency, 1987, Hossain et al., 2009, Khan and Rahman, 2010). Substrate type of the lake is clay with patches of silt and woody debris and its aquatic vegetation consists of macrophytes [Eichhornia crassipes (Mart) Solms, Pistia stratiotes				Management Committee]. The Management Body is comprised of the following members: Chief Executive officer, DCC; Chief Engineer, PWD; Chief Engineer, DCC; Chief Engineer, or Additional Chief Engineer, LGED; Consultant of the Project, Vitti Sthapati Brinda Ltd. It is noted that, public participation was apparently ignored in the Dhanmondi Lake Development project. The scenario of Dhanmondi area before the lakeside development differs strongly and it is portrayed in the change in land use pattern of the present. However, it receives many criticisms specially for its scale and nature of development which conflicts with the neighborhood environment (Sultana and Chowdhury, 2013).

	(Linnaeus, 1753) and Telanthera philoxeroides (Mart.) (Moq., 1849)] (Parveen et al., 1995). The lake features a number of fish species including Silver Carp [Hypophthalmichthys molitrix (Valenciennes, 1844)], Catla [Catla catla (Hamilton, 1822)], Rohu [Labeo rohita (Hamilton, 1822)], Pangas Catfish [Pangasius pangasius (Hamilton, 1822)], Nile Tilapia [Oreochromis niloticus (Linnaeus, 1758)] and Grass Carp [Ctenopharyngodon idella (Valenciennes, 1844)] (GWC, unpublished data; Chowdhury, Zieritz and Aldridge, 2015). One study was conducted during (2015) to assess the role, function and importance of freshwater mussels in Dhanmondi Lake from which two species of mussels [Lamellidens marginalis				

	(Lamarck, 1819) and Parreysia caerulea (Lea, 1831)] were found in the near shore zone of the lake. The lake and its biodiversity are facing severe anthropogenic pollution (Hossain et al., 2010; Razzak et al., 2012; Mokaddes et al., 2013). Despite high levels of organic and inorganic pollutants, the water of the lake is surprisingly clear with remarkably high biodiversity. Study indicates that the reason of such water quality is for the presence and functions served by dense populations of freshwater mussels like Lamellidens marginalis (the major contributor) and Parreysia caerulea (the minor contributor) who are pivotal in maintaining the functioning of a freshwater ecosystem in the center of Dhaka. In				

	this way, it can be noted that, these mussels support biodiversity, provide high-quality habitat conditions in Dhanmondi Lake and clear water to thousands of people inhabiting the surrounding area (Chowdhury et al., 2015).				
Gulshan-Baridhara Lake	Once upon a time, all the lakes of Dhaka city were interconnected through canals which are still an integral part of the eco-system and act as water retention basins during the monsoon, provide sources of biodiversity along with scenic beauty of the area. Gulshan Lake is one of the last remaining largest water bodies of the city serves as an important hydrological function of draining and detaining storm sewer from exclusive VIP zone of Dhaka city. Being the largest remaining water	Not Available	Though Gulshan Lake has a professional leasing system for fish cultivation and fish-feed, due to contamination from household solid waste from lakeside residents, fish mortality becomes an inevitable issue here (Sabit, 2011).	Not Available	Department of Environment (DoE) is in the charge of monitoring the cleanliness of Gulshan-Baridhara Lake which is declared as an ecologically critical area. Though Rajdhani Unnayan Kortripokhho (RAJUK) owns the lake, they leased it out to Bangladesh Fisheries Development Corporation (BFDC) on five years basis whereas, BFDC is in charge of introducing land and aquatic organisms as well as fish. RAJUK, took initiative for improvement of this lake. As there are illegal domestic sewage connections to storm sewers, DWASA also took up projects to expand storm and domestic sewer networks in Gulshan area

	body, it is a major source of recharging the ground water along with sustenance of the eco-system. This lake encircled the neighborhoods of Gulshan, Banani and Baridhara areas and made them the most exclusive residential areas of the city. Meanwhile, severe encroachment led to the disappearance of large portions of the lake and whatever is left is also threatened by land-grabbing and rampant pollution, killing the aquatic life in the lake and endangering its ecological balance. As the Dhaka Water Supply and Sewerage Authority (DWASA) has no sewer network in Badda and Baridhara areas, domestic sewers along with domestic waste is directly connected and dumped into the lake				as it is intergraded with the lake and causes pollution (Sabit, 2011).

	regularly. Besides, more than 12,000 cubic meters of untreated toxic chemical and human wastes from Tejgaon, Badda, and Pragati Sarani are dumped every day into the lake. Storm water runoff discharging into the lake also contains significant waste load. Moreover, sedimentation reduced the water retention capacity of the lake drastically (Chowdhury et al., 1998). Gulshan-Baridhara Lake is mainly used for pisciculture at present. Press report showed that the Department of Environment found the lake water heavily contaminated and unfit for the survival of aquatic species. Besides, sedimentation and toxic contamination are the pollution factors which damaged the essential features of the lake. This				

	lake has private enterprises who cultures fishes often find dead fishes afloat at many points which indicates fish killing incidents are quite common in different stretches of this lake. These incidents create negativity on the surrounding residents' minds for having products from this lake as well as attributed to the severe contamination of the lake, especially during the dry season. When the sample water was tested, it revealed that the dissolved oxygen (DO) of water was only 0.5 mg/ l (near zero) whereas fishes survival required 5 mg/ l (Sabit, 2011).				
Hatirjheel Lake	Hatirjheel portrayed a typical example of encroachment with illegal structures (Stilt bamboo houses along with permanent built	-	-	-	The government took a large project of urban renewal to develop the low-lying areas as a storm water retention basin in order to minimize the risks of floods into the nearby areas and

	form) which covered a large part of the lake edge with no municipal services. These squatters appeared due to Dhaka's growth in population which further affected the physical environment of the lake. Previously, some parts of this lake were used for rice cultivation when the water level was low. Besides, the lake was covered with overgrown hyacinths. The natural system of this lake was interrupted over the past decade and caused flooding and water logging (as a large amount of storm water with excess water from the rivers was retained which could not be drained and it crawled down to this water body as it was topographically a low area in the surroundings). This situation was reversed in the dry season and				to protect from further encroachment (Peeters and Shannon, 2009). RAJUK, 16 Engineering Construction Battalion of Army, DCC, DWASA, BUET, LGED, concerned Ministries, Special Works Organization SWO (West) of the Bangladesh Army were the institutions and agencies involved in this project (Islam, 2009). Among these organizations, BUET performed related researches, topographic survey, EIA, overall planning, design and top supervision; RAJUK was responsible for land acquisition, excavation, sludge removal/ disposal and slope protection; LGED was responsible for construction of peripheral road system, walkways, bridges, viaduct, landscaping, tree plantation and recreational facilities; DWASA performed main and local diversion sewer and SSDSs construction; SWO (West) of the Bangladesh Army entrusted overall implementation of all project components of RAJUK, LGED and DWASA on

	caused low water level. Domestic waste, solid waste, polluted industrial water from the factories next to this lake as well as the storm and wastewater from neighborhoods made this water body not as an amenity but as a backside of the city (Peeters and Shannon, 2009).				Hatirjheel water body (Unpublished report of SWO (West) and LGED, 2013).
Ramna Lake	Ramna Lake is located inside the Ramna Park area of Ramna thana and the area of the lake is 8.76 acre (Razzak et al., 2013) (cited in Islam et al., 2015). Its width varies from 9-94 m to some points and the lake is 812 m long (Razzak et al., 2013) (cited in Islam et al., 2015). From a study, eight (08) fish species were identified in the Ramna water body. Total of 151 plant species has been found surrounding Ramna Park areas (Pasha et al., 2021).	In Dhaka city, Ramna Lake is located in the middle part of the city that close to Shahbag areas (Sarkar et al., 2019). The lake is about 8.76 acres and its 72% of the total area exist in Shahbag region and has been playing a vital role in maintaining the only drainage system of Shahbag and Kakrail areas (Sarkar et al., 2019).	Not Available	Not Available	Ramna Lake is maintained by the Public Works Department (PWD) (Murshed, 2012) (cited in Rajia et al., 2015).

	This area is mainly plain land with a moderate number of flora and fauna. 71 species of flowering trees shrubs, perennials and annuals, 36 species of plants on fruit bearing, 33 species of medicinal plants, 41 species of forestry and other 11 species have been growing in Ramna Park area (Rajia et al., 2015). A total of 50 species of birds were found (Rajia et al., 2015).				
Diabari Bottola Lake	Not Available	Not Available	Not Available	Not Available	Not Available
Ashulia Urban Wetland	Not Available	Playing a vital role as catchment area, this water body facilitates the drainage of Dhaka city in the wet season (Begum, 2011; Sultana, 2012).	Ashulia sub-urban water body has high agricultural value as it contributes in the community livelihood during dry season. Besides, it provides immense opportunity for fishing and boating facilities from May to	Conservation of natural resources need enforcement of laws, policies and regulations which is absent in this urban	Though Paurashavas, Union Parishad etc. are the responsible authorities in this area, no support from these organizations were noticed and little access to legal and institutional support were seen. Besides, a number of sectoral agencies under different ministries are given responsibilities for this area where local organization as

			September (Begum, 2011; Sultana, 2012).	water body (Islam, 2009).	Union Parishad (UP) is the local administrative body and general people have access to the elected chairman along with his committee members (Islam, 2009).
Birulia Urban Wetland	Birulia is situated near Ashulia by the Turag River (Islam and Adnan, 2017). This Turag River is one of the polluted rivers in Bangladesh (Rahman, 2012) and it has very poor water quality due to dense, congested and unplanned growth of industries and housing on the bank of the river which turns the river as extensively dumping grounds might be responsible for the lower abundance of plankton community (Sadat et al., 2020). From the study, it is evident that the water of selected spots is now in crucial condition. Water being polluted day by day by chemical and organic	This water body is originated from the Turag River. But this is disconnected from the river during dry season and connected with the river in rainy season. In dry season it is almost dried up. There are many mills and factories are constructed near the Birulia water bodies and they use the water for cooling purposes during the manufacturing of their goods and finally release their wastes into the water after cooling operations, which increases the water and air temperature (Sadat et al., 2020).	Not Available	Not Available	Not Available

	wastes. In a consequence the Dissolved Oxygen concentration and pH level in these water bodies becomes very low at some locations. The reduction of DO value may be caused by high level of industrial sewage effluent and discharge of organic materials into the water which deteriorate DO content (Sadat et al., 2020).				

4.3 Concluding Remarks

This chapter discussed the current status, existing role and challenges on management and use of some urban wetlands case studies on urban wetlands according to the ‘Urban Wetland Sustainability Framework (UWSF) Model – 1’ on the Global and Dhaka City Context.

CHAPTER - V

FINDINGS AND ANALYSIS - 2

This study delivers the essence that, for sustainable conservation and management of urban wetlands and appropriate revival measures, it is necessary to involve stakeholder's perceptions within overall management process who are directly engross with the water body. This chapter discussed the results of stakeholder perceptions of selected urban wetlands according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' that followed by the first, second and fifth objectives and research questions of the study.

5.1 Applicability of the Urban Wetland Sustainability Framework (UWSF) Model – 1 on the Selected Study Area Context

Traditionally urban wetlands have been playing an important function in the city of Dhaka. These wetlands have been supporting multidimensional role as conservation of biodiversity, microclimate preservatives, reducing the effect of urban heat islands effect, storm water retention basins, recharge of ground aquifer for drinking water, improving the water quality through natural filtration systems, community livelihood contribution, act as aesthetic greenery waterfront recreational space and others. But at present, due to urban development activities, encroachment, high population density, lack of awareness among urban dwellers towards conservation, high intensity of pollution, climate change impacts, lack of enforcement of policies, lack of sustainable management, lack of stakeholder involvement on management and planning and other threats in the city, many of these urban wetlands have been degrading and dying. Recently, there exists unsustainable urban wetlands in Dhaka city.

For different natural and anthropogenic external factors, the water quality of maximum urban wetlands has been deteriorating which finally disturbs the freshwater ecosystems and the ecological services they provide for the city. Therefore, these dying urban wetlands in the capital immediately need their sustainable restoration, revitalization, re-integration, properly planned, conserved and finally need to manage to remain livable as a whole. The literature reviews show that, specific study on the urban wetland management concerning sustainability paradigm on the study area of Dhaka has been less documented previously (Chapter - I: Introduction and Chapter - II: Literature Review and Analytical Framework). Under these circumstances, considering all the constraints and challenges in the city, this research entails the current scenario, existing role and challenges of selected urban wetland management and use in Dhaka city as the case from the stakeholder's perspective according to 'Urban Wetland Sustainability Framework (UWSF) Model - 1' which followed by IUCN Integrated Wetland Assessment Toolkit that already discussed in the Chapter - II: Literature Riview and Analytical Framework and Chapter - III: Methodology and Study Area. This research reveals how the stakeholder's perception can contribute to the sustainability of wetland management of a city to various theoretical frameworks which will further contributes the development of the country. These information and gaps can reach the decision makers, policy makers, management bodies for overall sustainable development of these urban wetlands in future. Therefore, this chapter tried to identified the first, second and fifth research questions answers as follows. These research questions are **(1)** what are the current status and existing role of selected urban wetlands according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1'? **(2)** what are the challenges of selected urban wetlands management and use according to 'Urban Wetland Sustainability Framework (UWSF) Model – 1'? and **(5)** what are the recommendations for sustainable conservation and management of selected urban wetlands according to 'Urban Wetland Sustainability Framework (UWSF) Model – 1'? To identify the above research questions, all information has been extracted from study area stakeholder perceptions, institutional stakeholder expert's perceptions of relevant organizations/institutions and author personal field observation as follows:

(I) Study Area Stakeholder Perceptions

This section discussed the results of study area stakeholder perceptions on semi-structured questionnaire survey according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' in seven study areas.

5.1.1 Current Scenario and Existing Role of Selected Urban Wetlands According to the Urban Wetland Sustainability Framework (UWSF) Model – 1

As previously discussed in Chapter - III: Methodology and Study Area, 'Urban Wetland Sustainability Framework (UWSF) Model – 1' have been developed in this research with five attributes of the sustainability that followed by IUCN Integrated Wetland Assessment Toolkit on the context of Bangladesh. These selected five attributes are 'contribution for biodiversity conservation and enhancement', 'resilience of urban water body to face the challenge of climate change impacts', 'contribution for community livelihood', 'adequacy of the policy regime' and 'local acceptance and credibility of the role of relevant institutions' etc. Seven study areas have been selected that previously discussed as Study area - 1: Dhanmondi Lake, Study area - 2: Gulshan-Baridhara Lake, Study area - 3: Hatirjheel Lake, Study area - 4: Ramna Lake, Study area - 5: Diabari Bottola Lake, Study area - 6: Ashulia urban wetland and Study area - 7: Birulia urban wetland etc. This section prefers the current scenario and existing role of selected urban wetlands according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' from study area stakeholder perceptions with thirty nos. purposive samples from each study area and analyzed with five-point Likert scale that followed the first objective and the first research question that have been developed in this research.

5.1.1.1 Attribute - 1: 'Contribution for biodiversity conservation and enhancement'

Urban wetland has an important function to conserve their aquatic and terrestrial biodiversity conservation in any city. On this connection, aquatic plant diversity, fish species, other aquatic animal species, terrestrial tree species, terrestrial wildlife species, terrestrial bird species (by using english and local name) and perceptions according to the scale of contribution have been extracted from each study area stakeholder perceptions on this attribute that discussed as follows:

5.1.1.1.1 Study area - 1: Dhanmondi Lake

(a) Aquatic Plant Diversity

According to study area stakeholder perceptions, this water body have been contributing total three (3) species of aquatic plants as Water Lily (Shapla), Water Spinach (Kolmi), Water Hyacinths (Kochuripana) etc.

(b) Fish Species

Total twenty-one (21) species of fishes as maximum availability of Bighead carp (Brigade - 1 to half kg weight max.), Rohu (Rui - 4 kg weight max.), Catla (Catla - 7 to 8 kg weight max.), Tilapia (Tilapia), Grass carp (Grass carp), Chinese carp (Carphu), Mrigal carp (Mrigal), Black carp (Black carp), Glass fish (Chanda), Gojar-striped snake head (Gojal), Snake head (Taki), Puntius fish (Puti), Mola fish (Mola), Dhela fish (Dhela), Khoilsha fish (Khoilsha), River catfish (Pangash-cultivating presently) etc. and other fishes as African catfish (Australian Magur), Striped snake head (Shole), Stinging catfish (Shing), Climbing perch (Koi), Silver carp fish (Silver carp) etc. already decreased in recent years have been identified.

(c) Other Aquatic Animal Species

Total five (5) species of aquatic wildlife species as Snail (Shamuk - decreased than before), Oyster (Jhinuk - decreased than before), very few quantities of Small Crab (Kakra - as some fishes consume kakra), Snake (Shap - dora shap mainly), Frog (Bang) etc. have been identified.

(d) Terrestrial Tree Species

Total sixteen (16) species of terrestrial trees (plants, trees, vegetation etc.) as varieties of green plants, shaded lot of trees as Chambul tree (Chambul), Banyan tree (Bot), Mahogany (Mehogoni), Siris tree (Koroi), Raintree (Raintree), Royal Poinciana (Krishnochura), Golden Shower tree (Shonalu), Barringtonia acutangula (Hizol), Bitter oleander (Kurchi), Jackfruit (Kathal), Mango (Aam), Plum (Boroi), Water apple (Jamrul), Berry (Jam), Azadirachta indica (Neem) etc. are available on the both bank sides of this lake have been identified.

(e) Terrestrial Wildlife Species

Total nine (9) species of terrestrial wildlife as Squirrel (Kathbirali), Swan (Rajhash), Duck (Hash), Dog (Kukur), Cat (Biral), Butterfly (Projapoti - less), Grasshopper (Foring), Bee (Moumachi - very less), Mongoose (Beji) etc. have been identified.

(f) Terrestrial Bird Species

Total twelve (12) species of terrestrial birds as Cuckoo (Kokil), Passerine birds (Bulbuli), Black Hooded Oriole (Bou Kotha Kou), Ploceidae (Babui), Alexandrine Parakeet (Tia), Oriental magpie-robin (Doel), Sparrow (Choroi), Crow (Kak), Gracula (Shalik), Black Kite (Cheel), Pigeon (Kobutor) and other varieties of small birds etc. have been identified.

(g) Study Area Stakeholder Perceptions According to the Scale of Contribution on Attribute - 1

According to the study area stakeholder perceptions it was identified that, in Study area - 1: Dhanmondi Lake, 16.67% stakeholders think that this water body has been performing ‘effective contribution’ for biodiversity conservation and enhancement as much varieties of local fishes are still available in this water body; good taste of fishes; less quantities of fishes found dead; less bad odor in the water; fishes found more in monsoon season than dry season for enough availability of rain water; much varieties of plants, shaded trees are available on the both banks; much varieties of birds are available etc. 73.33% stakeholders think ‘moderately effective contribution’ as quantity and quality of fishes has been declining in recent days than before for polluted water; some local varieties of fishes have been declining than before for changing of water quality; wastes from surrounding domestic and commercial set up mainly in rainy season polluting this lake and for these reasons, the quantity of fishes and other aquatic animals will decline in near future; public pollutes this water body by throwing waste for less awareness sometimes; few fishes found dead in winter and rainy season mainly for pollution disposal and surface runoff; bad odor of water found mainly in winter season sometimes; fish farmers using medicine, potash, chun and other powder for cleaning of polluted water; need to provide additional fish food often in the lake water from fish farmers; presence of viruses in water (according to authorities information that mentioned by respondent); aquatic fauna as shamuk and jhinuk are declining than before in this water body; water lily, lotus etc. cannot live for public disturbance (several times authorities planted these aquatic flora, but public pulled these plants from water); less flower plants surrounding the water body; less butterfly availability in lake surrounding; bees are almost absent in lake surrounding; people cannot use lake water for drinking etc. 6.67% stakeholders think ‘less effective contribution’ as water is not good in recent days for pollution and 3.33% stakeholders have ‘no idea’.

5.1.1.1.2 Study area - 2: Gulshan-Baridhara Lake

(a) Aquatic Plant Diversity

In this water body, total two (2) species of aquatic plants as Water Spinach (Kolmi), Water Hyacinths (Kochuripana) etc. have been identified.

(b) Fish Species

Total eleven (11) species of fishes as maximum availability of River catfish (Pangash - 20 to 25 kg weight max. and more than 4 to 5 feet long), Tilapia (Tilapia), Catfish (Magur) etc. and very less availability of Catla (Catla), Rohu (Rui), Chitol fish (Chitol - 30 to 40 kg weight max.), Climbing perch (Koi), Khoilsha fish (Khoilsha), Striped snake head (Shole), Stinging catfish (Shing), etc. and other small local fishes as Chapila fish (Chapila), Tangra fish (Tangra), Puntius fish (Puti), Small shrimp (Chingri) etc. already disappeared for long time have been identified.

(c) Other Aquatic Animal Species

Total four (4) species of aquatic wildlife species as Snake (Shap), Snail (Shamuk), Oyster (Jhinuk), Frog (Bang) etc. have been identified.

(d) Terrestrial Tree Species

Total twelve (12) species of terrestrial trees (plants, trees, vegetation etc.) as Royal Poinciana (Krishnochura), Peacock flower (Radhachura), Almond tree (Badam), Jackfruit (Kathal), Giant crepe-myrtle (Jarul), Banana (Kola), Azadirachta indica (Neem), Golden Shower tree (Shonalu), Mango (Aam) etc. are available on the Gulshan bank side of this lake mainly and Badda bank side has been recently planting different fruit trees (as Mango (Aam), Papaya (Pepey), Jackfruit (Kathal), Lemon (Lebu), Banana (Kola), Guava (Peara), etc.) and fresh vegetables (as Bottle gourd (Lau), Wax Gourd (Kumra), Beans (Sim), (Kopi), Red Spinach (Lal shak), Spinach (Palong shak) etc.) have been identified.

(e) Terrestrial Wildlife Species

Total six (6) species of terrestrial wildlife as Dog (Kukur), Cat (Biral), Squirrel (Kathbirali), Duck (Hash - few), Butterfly (Projapoti - less), Grasshopper (Foring - less) etc. have been identified.

(f) Terrestrial Bird Species

Total five (5) species of terrestrial birds as Sparrow (Choroi), Oriental magpie-robin (Doel), Gracula (Shalik), Pigeon (Kobutor), Crow (Kak) etc. have been identified.

(g) Study Area Stakeholder Perceptions According to the Scale of Contribution on Attribute - 1

In Study area – 2: Gulshan-Baridhara Lake, 66.67% stakeholders think that this water body has been performing ‘less effective contribution’ for biodiversity conservation and enhancement as water quality is not good; for bad water quality and smell, fishes also found with bad smell and taste; bad smell of water especially in winter season; local carp type fishes cannot live in this polluted water; fishes found dead when there is gas occurred in lake water; for bad smell fish lease holders and fish farmers have been using potash, chun etc. and they also cleaning the lake frequently (at present situation, smell is improving slightly, fishes also found less in smell and taste is improving than before slightly; Local Government authorities and community people of Badda as all fish lease holders side stopped sources of pollution from surrounding area recently); need to provide additional fish food often in the lake water by ‘commercial fish lease holder’ authorities; water quality is so bad recently that, local people cannot even use lake water for bathing, washing, drinking etc. now in this lake; only Pangash, Magur, Tilapia etc. can live moderately, but other local fishes as Rui, Katla cannot live in this bad quality of water, there number are very few here; when fish lings are providing in this lake water, nearly 5% to 10% fishes are die normally for bad quality of water firstly; in the past, the water was good, much varieties of local fish species as Chapila, Puti, Tangra, Chingree etc. can live here, but recent times for surrounding development, encroachment and pollution these fishes cannot live in this lake, every year fishes found floated dead on the top surface of the water body; for bad water quality, local fish species have been endangered already and if this present situation will continued, it will be very difficult for rest of species to live in this water body in near future effectively; once this lake was a good fishing ground for urban dwellers, many people from different parts of Dhaka city come to this lake for taking of fishes from here, that time those fishes were in very good quality; once local people used to drank water from this lake, but now that situation completely changed, people cannot use lake water for drinking for bad water quality; surrounding pollution from domestic, industrial, clinical, construction waste and waste water from both sides of residential areas as Gulshan and Badda and from surrounding commercial areas; sewerage line connection from both sides of residential areas as Gulshan and Badda has been polluting the lake water; absence of water plants as water lily, lotus etc; less flower plants surrounding the water body; less butterfly, dragonfly, bees etc. availability in lake surrounding; birds found here, but declining than the past for bad water quality and bad smell of water etc. 26.66% stakeholders think ‘not effective at all’ as not suitable for fishes and other aquatic animals to live for surrounding waste pollution; every year fishes found dead floated on the top surface of the water body for bad quality of water; pollution from surrounding areas; direct sewerage pipe line connection from Gulshan and Badda areas to the water body etc. and 6.67% stakeholders have ‘no idea’.

5.1.1.1.3 Study area - 3: Hatirjheel Lake

(a) Aquatic Plant Diversity

In this water body, total one (1) species of aquatic plants as Water Hyacinths (Kochuripana) etc. have been identified.

(b) Fish Species

Total ten (10) species of fishes as much availability of River catfish (Pangash - 22 to 25 kg weight max.), Catfish (Magur - 25 kg weight max.), Stinging catfish (Shing), Climbing perch (Koi) etc. and very less availability of Rohu (Rui), Catla (Catla), Mrigal carp (Mrigal), Tilapia (Tilapia), Silver carp fish (Silver carp) and other small fishes etc. have been identified.

(c) Other Aquatic Animal Species

Total five (5) species of aquatic wildlife species as Frog (Bang), Snake (Shap), Snail (Shamuk), Oyster (Jhinuk), small Turtle (Kochop) etc. have been identified.

(d) Terrestrial Tree Species

Total sixteen (16) species of terrestrial trees (plants, trees, vegetation etc.), among fruit trees as Mango (Aam), Jackfruit (Kathal), Water apple (Jamrul), Plum (Boroi), Date tree (Khejur), Banana (Kola), Berry (Jam), Palm tree, (Palm) etc. flowery trees as Royal Poinciana (Krishnochura), Giant crepe-myrtle (Jarul), Burflower-tree (Kodome), Golden Shower tree (Shonalu), Raintree (Raintree), Hibiscus (Joba) etc. timber trees as Gorjan tree (Gorjan), Gojari tree (Gojari) etc. are available on the both bank sides of this lake have been identified.

(e) Terrestrial Wildlife Species

Total six (6) species of terrestrial wildlife as Mongoose (Beji), Squirrel (Kathbirali), Dog (Kukur), Cat (Biral), Butterfly (Projapoti - less), Grasshopper (Foring - less) etc. have been identified.

(f) Terrestrial Bird Species

Total five (5) species of terrestrial birds as White Egret birds (Shada bok), Oriental magpie-robin (Doel), Gracula (Shalik), Sparrow (Choroi), Crow (Kak) etc. have been identified.

(g) Study Area Stakeholder Perceptions According to the Scale of Contribution on Attribute - 1

In Study area - 3: Hatirjheel Lake, 10.0% stakeholders think that this water body has been performing ‘less effective contribution’ for biodiversity conservation and enhancement as fishes cannot found often, observed very less in quantity; bad smell in water etc. 86.67%

stakeholders think ‘not effective at all’ as water quality is not good; not suitable for fishes and other animals to live for waste pollution; fishes found dead often for bad water quality (as koi, pangash etc.); fishes found taste with bad odor normally; for bad water quality, fishes cannot get proper oxygen and died; water gets polluted and blackish by Kawron bazar waste disposal; solid waste pollution from Rampura area, pollution from fish market, defecation pollution, bathing, waste water from surrounding drain etc. disposed to this lake; surrounding waste, waste water disposed directly in this lake; Bangladesh Army use bleaching powder, but water quality is not improving as expected; people cannot use lake water for drinking for bad water quality; less flower plants surrounding the water body; less butterfly, dragonfly, bees etc. availability in lake surrounding; less quantity of birds found here, as birds cannot live here for bad water quality and bad smell etc. and 3.33% stakeholders have ‘no idea’.

5.1.1.1.4 Study area - 4: Ramna Lake

(a) Aquatic Plant Diversity

This water body have been contributing total three (3) species of aquatic plants as Water Spinach (Kolmi), Water Hyacinths (Kochuripana), Water Lettuce (Topapana) etc.

(b) Fish Species

Total thirteen (13) species of fishes as Silver carp fish (Silver carp), Bighead carp (Brigade), Rohu (Rui), Catla (Catla), Tilapia (Tilapia), Stinging catfish (Shing), Catfish (Magur), River catfish (Pangash), Mrigal carp (Mrigal), Minnows (Tatkini), Small shrimp (Chingri), Striped snake head (Shole), Snake head (Taki) etc. have been identified.

(c) Other Aquatic Animal Species

Total six (6) species of aquatic wildlife species as lots of Snail (Shamuk) and Oyster (Jhinuk), Snake (Shap), Crab (Kakra), small Turtle (Kochop), Frog (Bang) etc. have been identified.

(d) Terrestrial Tree Species

Total fifteen (15) species of terrestrial trees (plants, trees, vegetation etc.) as huge quantities of fruit trees and flower plants as Giant crepe-myrtle (Jarul), Royal Poinciana (Krishnochura), Raintree (Raintree), Azadirachta indica (Neem), Mango (Aam), Jackfruit (Kathal), Water apple (Jamrul), Berry (Jam), Plum (Boroi), Banana (Kola), Bullet Wood (Dumur), Bokul tree (Bokul), Almond tree (Badam), Gooseberry (Amloki) and Coconat (Narikel) etc. are available on the both bank sides of this lake have been identified.

(e) Terrestrial Wildlife Species

Total nine (9) species of terrestrial wildlife as Duck (Hash), Swan (Rajhash), Cat (Biral), Dog (Kukur), Squirrel (Kathbirali), Mongoose (Beji), Butterfly (Projapoti), Grasshopper (Foring), Bee (Moumachi) etc. have been identified.

(f) Terrestrial Bird Species

Total six (6) species of terrestrial birds as Cormorant (Pankouri), Oriental magpie-robin (Doel), Egret birds (bok), Gracula (Shalik), Alexandrine Parakeet (Tia), Crow (Kak) etc. have been identified.

(g) Study Area Stakeholder Perceptions According to the Scale of Contribution on Attribute - 1

In Study area - 4: Ramna Lake, 63.33% stakeholders think that this water body has been performing 'effective contribution' for biodiversity conservation and enhancement as water quality is good, less polluted and less bad odor etc.; suitable for fishes and other species to live; much varieties of local fishes are available as before in this water body; taste of fishes is good to eat as before; fish quality is almost same as it was before; fishes do not found dead floated on the water body normally except some times in rainy season; no outside outfalls or pipes are connected that can pollute the water of Ramna Lake by external waste and waste water; fishes consume natural food from lake water, no need to provide additional food from authorities; no need additional chemical or medicine for clean the lake water frequently ('City Division' of PWD authorities only use 'chun' within one year interval only); fishes found in monsoon season more than winter season for enough availability of water; there are lot of aquatic fauna as shamuk and jhinuk available in this water body; different aquatic animals are available; a lot of plants, shaded trees, flowers plants and trees are available surrounding the water body; much varieties of butterfly, dragonfly and bees are available in the lake surrounding; much varieties of birds are available etc. 16.67% stakeholders think 'moderately effective contribution' as fishes sometimes found dead floated on the water in monsoon season as surrounding commercial area's polluted water mixed with this water body etc. and 20.0% stakeholders have 'no idea'.

5.1.1.1.5 Study area - 5: Diabari Bottola Lake

(a) Aquatic Plant Diversity

This water body have been contributing total three (3) species of aquatic plants as Grass type local thin plants, Water Spinach (Kolmi), Water Hyacinths (Kochuripana), etc.

(b) Fish Species

Total seventeen (17) species of fishes as Bighead carp (Brigade), Chitol fish (Chitol), Rohu (Rui), Catla (Catla), Silver carp, Grass carp (Grass carp), Chinese carp (Carphu), Mrigal carp (Mrigal), River catfish (Pangash), Tilapia (Tilapia), Stinging catfish (Shing), Catfish (Magur), Climbing perch (Koi), Tangra fish (Tangra), Small indigenous species (Guramach), Khoilsha fish (Khoilsha) and other small fishes etc. have been identified.

(c) Other Aquatic Animal Species

Total four (4) species of aquatic wildlife species as Frog (Bang), Snake (Shap), lots of Snail (Shamuk) and Oyster (Jhinuk), etc. have been identified.

(d) Terrestrial Tree Species

Total six (6) species of terrestrial trees (plants, trees, vegetation etc.) as varieties of green plants, Willow and hazel (Kashful), very less trees as Plum (Boroi), Banana (Kola), Royal Poinciana (Krishnochura), Papaya (Pepey) etc. have been identified.

(e) Terrestrial Wildlife Species

Total nine (9) species of terrestrial wildlife as Lamb (Vera), Goat (Chagole), Cow (Goru), Hen (Murgi), Horse (Ghora), Mongoose (Beji), lots of Butterfly (Projapoti), Grasshopper (Foring), Bee (Moumachi) etc. have been identified.

(f) Terrestrial Bird Species

Total eleven (11) species of terrestrial birds as Spotted dove (Ghugu - eat fishes), Black Owl (Kalo Pacha), Oriental magpie-robin (Doel), Ploceidae (Babui), Pigeon (Kobutor), Ferruginous ducks (Bali Hash - come from other places), White Egret birds (Shada bok - eat fishes), Sparrow (Choroi), Gracula (Shalik), Crow (Kak), Gobrakani etc. have been identified.

(g) Study Area Stakeholder Perceptions According to the Scale of Contribution on Attribute - 1

In Study area - 5: Diabari Bottola Lake, 6.67% stakeholders think that this water body has been performing ‘very effective contribution’ for biodiversity conservation and enhancement as water is very much clean for fishes to live; varieties of fishes are available. 76.66% stakeholders think ‘effective contribution’ as water is less polluted and absence of bad smells; good for fishes and other aquatic species to live; much varieties of local fishes are available; taste of fishes is good to eat; fishes do not found dead floated on the water body normally for less pollution; fish farmers clean the water frequently and do not allow any pollution disposal in the lake water, example as oil seepage or other pollution with proper maintenance; during dry season (month of October) and rainy season few fishes found dead for surface runoff but their number is very less; some fishes found dead when fishermen catch fishes by net; there is no outside outfalls, pipes (only inside area storm water pipes are available) are connected that can pollute the water of the lake by external waste and waste water (Turag River connection is blocked now by gate); less pollution from surrounding under developed areas still now; fishes found in monsoon season more than winter season for enough availability of water; in rainy season when water depth reached at maximum level, lake water found clear and soil of the bed is visible that time from the bank; different aquatic animals are available; there are lot of aquatic fauna as shamuk and jhinuk available in this water body; animal, birds etc. use to drink this lake water often; lake water is good for plants, trees of nurseries also; much varieties of butterfly, dragonfly and bees are available in the lake surrounding for presence of plants, trees from nurseries; much varieties of birds are available; a lot of people take bath in this lake and do not get affected by any diseases for bathing, washing of lake water etc. 10.0% stakeholders think ‘moderately effective contribution’ as fish farmers have been using medicine (5 to 6 nos. packets for one day) for cleaning of lake water; need to provide additional fish food often in the lake water by fish farmer; some floating waste comes from surrounding area in rainy season; storm water pipes and surface runoff outfall can be harmful in future for convey of pollution in the lake when urban development will increase; pollution by public sometimes; people cannot use lake water for drinking; absence of water plants as water lily, lotus etc.; very less of plants, shaded trees, flowers plants and trees are available surrounding the water body (RAJUK have planned to plant these trees in coming future) etc. and 6.67% stakeholders have ‘no idea’.

5.1.1.1.6 Study area - 6: Ashulia urban wetland

(a) Aquatic Plant Diversity

This water body have been contributing total two (2) species of aquatic plants as Water Spinach (Kolmi), Water Hyacinths (Kochuripana) etc.

(b) Fish Species

Total twenty-one (21) species of fishes as Tangra fish (Tangra - maximum availability), River catfish (Aire), Bime-eel (Baine), Catfish (Magur), Stinging catfish (Shing), Climbing perch (Koi), Rohu (Rui), Catla (Catla), Khoilsha fish (Khoilsha), River catfish (Boal), Striped snake head (Shole), Gobby (Beley), Silver carp fish (Silver carp), River catfish (Pangash), Mola fish (Mola), Dhela fish (Dhela), Snake head (Taki), Puntius fish (Puti), Meni fish (Meni), Small shrimp (Chingri), Tilapia (Tilapia) etc. have been identified.

(c) Other Aquatic Animal Species

Total six (6) species of aquatic wildlife species as local Dolphin (Shushokh), lots of Snail (Shamuk) and Oyster (Jhinuk), Frog (Bang), small Turtle (Kochop), Snake (Shap) etc. have been identified.

(d) Terrestrial Tree Species

In this study area species of terrestrial trees are absent surrounding this water body.

(e) Terrestrial Wildlife Species

Total five (5) species of terrestrial wildlife as Mongoose (Beji), Hen (Murgi), Duck (Hash), Butterfly (Projapoti - less), Grasshopper (Foring - less) etc. have been identified.

(f) Terrestrial Bird Species

Total seven (7) species of terrestrial birds as White Egret birds (Shada bok), Migratory birds (for only two months in winter season come to this water body), Crow (Kak), Gracula (Shalik), Sparrow (Choroi), Pigeon (Kobutor) and other varieties of small birds etc. have been identified.

(g) Study Area Stakeholder Perceptions According to the Scale of Contribution on Attribute - 1

In Study area - 6: Ashulia urban wetland, during dry season, 23.33% stakeholders think that this water body has been performing ‘less effective contribution’ for biodiversity conservation and enhancement as water almost dried during dry season; bad quality of water with bad smell in winter; less quantities of small fishes available in remaining wetland water during dry period; less aquatic species available than the past etc. 70.0% stakeholders think ‘not effective at all’ as water almost dried during dry season; aquatic species go down with Turag River water when starting dry period; ashulia wetland surrounded by dead water of Turag River during monsoon and dry season; blackish water with very bad odor during dry time; fishes die in winter season mainly for surrounding waste water disposal from dyeing factories and other industries; water quality degradation for pollution as industrial, construction waste, chemical waste and waste water etc. (from dyeing and other factories and industries of Ashulia, Dhaka city, Gazipur and Tongi areas); bad smell in fishes for bad water quality; taste of fishes is not so good to eat as before; local species of fishes have been declining day by day; not good for fishes and other aquatic species to live; during rainy season, water pollution by oil seepage from water vessels in Turag River; once, local people used to drink wetland water directly, but now cannot use this water for drinking for bad water quality; trees cannot plant for presence of water all the time of six months of the year; no water plants as water lily, lotus is available etc. and 6.67% stakeholders have ‘no idea’.

In Study area - 6: Ashulia urban wetland, during rainy season, 3.33% stakeholders think that this water body has been performing ‘effective contribution’ for biodiversity conservation and enhancement as maximum availability of water in rainy season. 43.33% stakeholders think ‘moderately effective contribution’ as fishes availability for maximum availability of water in rainy season; water comparatively better in rainy season than dry season etc. and 53.33% stakeholders think ‘less effective contribution’ as bad smell in fishes; taste of fishes is not so good to eat as before; less fishes availability than before; local species of fishes have been declining day by day etc.

5.1.1.1.7 Study area - 7: Birulia urban wetland

(a) Aquatic Plant Diversity

This water body have been contributing total two (2) species of aquatic plants as Water Spinach (Kolmi) and Water Hyacinths (Kochuripana) etc.

(b) Fish Species

Total nineteen (19) species of fishes as River catfish (Pangash), Tangra fish (Tangra), Tilapia (Tilapia), River catfish (Aire), Climbing perch (Koi), Stinging catfish (Shing), Catfish (Magur), Rohu (Rui), Catla (Catla), River catfish (Boal), Striped snake head (Shole), Gobby (Beley), Khoilsha fish (Khoilsha), Mola fish (Mola), Dhela fish (Dhela), Snake head (Taki), Puntius fish (Puti), Meni fish (Meni), Small shrimp (Chingri) etc. have been identified.

(c) Other Aquatic Animal Species

Total seven (7) species of aquatic wildlife species as lots of Snail (Shamuk) and Oyster (Jhinuk), small Crab (Kakra), local Dolphin (Shushokh), small Turtle (Kochop), Snake (Shap), Frog (Bang) etc. have been identified.

(d) Terrestrial Tree Species

In this study area species of terrestrial trees are less in quantity, but some trees of total fourteen (14) species fringe of huge native trees surrounding the village as Plum (Boroi), Coconat (Narikel), Mango (Aam), Bullet Wood (Dumur), Stone apple (Bel), Betel nut palm (Supari), Jackfruit (Kathal), Narrow-leaved bottle tree (Bott), Berry (Jam), Water apple

(Jamrul), Lichi (Lichu), Guava (Peara), Palm tree (Tal), Azadirachta indica (Neem) etc. are available that have been identified.

(e) Terrestrial Wildlife Species

Total eight (8) species of terrestrial wildlife as Goat (Chagole), Cow (Goru), Mongoose (Beji), Monitor lizard (Guishap), Duck (Hash), Hen (Murgi), Butterfly (Projapoti - less), Grasshopper (Foring - less) etc. have been identified.

(f) Terrestrial Bird Species

Total six (6) species of terrestrial birds as White Egret birds (Shada bok), Crow (Kak), Gracula (Shalik), Pigeon (Kobutor), Sparrow (Choroi) and other varieties of small birds etc. have been identified.

(g) Study Area Stakeholder Perceptions According to the Scale of Contribution on Attribute - 1

In Study area - 7: Birulia urban wetland, during dry season, 16.67% stakeholders think that this water body has been performing ‘less effective contribution’ for biodiversity conservation and enhancement as water almost dried during dry season; less quantities of small fishes available in remaining wetland water during dry period etc. and 83.33% stakeholders think ‘not effective at all’ as negligible quantity of water in dry season; fishes go down with Turag River water when starting dry period; bad quality of water with bad smell in winter (nearly 20 to 25 feet height of water in front of Turag River distributaries); quantity of aquatic species already declining and every winter season fishes found dead floated; pollution from industrial, domestic, construction waste and waste water; water is bad in winter season; bad smell in fishes etc.

In Study area - 7: Birulia urban wetland, during rainy season, 36.67% stakeholders think that this water body has been performing ‘moderately effective contribution’ for biodiversity conservation and enhancement as maximum availability of water in rainy season; fishes availability for maximum availability of water etc. and 63.33% stakeholders think ‘less effective contribution’ as local fishes have been declining day by day; less availability of carp type of fishes; as this area situated in front of Turag River distributaries, much polluted water mixed with this flood plain in rainy season that has been degrading the water of this water body; taste of fishes is not so good to eat as before; water pollution by oil of large and small water transport; water pollution by bathing, washing of cloths and others etc.; people cannot use wetland water for drinking for bad water quality etc.

5.1.1.2 Attribute - 2: 'Resilience of urban water bodies to face the challenge of climate change impacts'

It has seen from different studies that urban water bodies be able to play an important role on the local and regional climate change impacts, heat absorbers, roughness, energy exchange and the best absorbers of radiation too. This attribute tried to find out the current status and existing role on resilience of urban water bodies to face the challenge of climate change impacts from study area stakeholder perceptions in seven study areas as follows:

(a) Study Area Stakeholder Perceptions According to the Scale of Contribution on Attribute - 2

In this research, the 'resilience of urban water bodies to face the challenge of climate change impacts' have been selected into two criteria for identification from stakeholder perceptions. These are cooling effect during summer on heat stress of selected urban wetlands and on storage capacity during heavy rainfall on flood stress of selected urban wetlands that discussed as follows:

5.1.1.2.1 Cooling Effect During Summer on Heat Stress of Selected Urban Wetlands

According to study area stakeholder perceptions it was identified that, in Study area - 1: Dhanmondi Lake, 86.67% stakeholders think that this water body has been performing 'effective resilience' for cooling effect as presence of lot of big shaded trees and water availability; much feel cool during rainy season. 10.0% stakeholders think 'moderately effective resilience' as cool during afternoon time mainly and 3.33% stakeholders have 'no idea'.

In Study area - 2: Gulshan-Baridhara Lake, 56.67% stakeholders think 'effective resilience' for cooling effect as presence of much water availability and lot of big shaded trees in Gulshan bank side. 33.33% stakeholders think 'moderately effective resilience' as non-availability of big shaded trees in Badda bank side; day time much hot in summer season; feel cool during night time. 3.33% stakeholders think 'less effective resilience' as no reason for choices and 6.67% stakeholders have 'no idea'.

In Study area – 3: Hatirjheel Lake, 73.33% stakeholders think 'effective resilience' for cooling effect as presence of enough water availability and big shaded trees in both bank sides; much feel cool during rainy season than summer. 24.34% stakeholders think 'moderately effective resilience' as cool during monsoon season mainly and 3.33% stakeholders have 'no idea'.

In Study area - 4: Ramna Lake, 90.0% stakeholders think 'effective resilience' for cooling effect as presence of lot of green big shaded trees, plants, vegetation etc. and enough water availability. 6.67% stakeholders think 'moderately effective resilience' as much feel cool during afternoon time and 3.33% stakeholders have 'no idea'.

In Study area - 5: Diabari Bottola Lake, during summer season, 26.67% stakeholders think 'moderately effective resilience' for cooling effect as in dry season, presence of water depth (nearly 35 feet) between afternoon (normally after 5 pm) to night time of the day; absence of big shaded trees on the banks. 53.33% stakeholders think 'less effective resilience' as much hot in day time; absence of big shaded trees on the banks and surrounding areas creates heat during noon (normally from 12 am) time). 16.67% stakeholders think ‘not effective at all’ as not feel cool; no big trees and 3.33% stakeholders have ‘no idea’. In Study area - 5: Diabari Bottola Lake, during monsoon season, 10.0% respondents think ‘effective resilience’ for cooling effect as in rainy season when maximum water depth (nearly 45 feet) is available, surrounding environment feel comparatively cool during morning to night time; absence of trees and 90.0% stakeholders think ‘moderately effective resilience’ for cooling effect as cool mainly afternoon time in rainy season.

In Study area - 6: Ashulia urban wetland, during summer season, 93.33% stakeholders think ‘not effective at all’ for cooling effect as non-availability of water (almost dried about 2 to 3 feet depth of water remaining); absence of big shaded trees inside or surrounding the water body (as big trees and plants cannot live for presence of water all the year and black smoke from brick manufacturing work in Ashulia floodplain) and 6.67% stakeholders have ‘no idea’. In Study area - 6: Ashulia urban wetland, during monsoon season, 10.0% stakeholders think ‘effective resilience’ for cooling effect as maximum water depth (nearly 12 to 13 feet) is available in rainy season, so, surrounding environment feel comparatively cool. 76.67% stakeholders think ‘moderately effective resilience’ as presence of water; cool mainly at afternoon to night time of the day. 13.33% stakeholders think ‘less effective resilience’ as absence of big shaded trees on the banks and surrounding areas.

In Study area - 7: Birulia urban wetland, during summer season, 16.67% stakeholders think ‘less effective resilience’ as surrounding water dried but there is 20 to 25 feet depth of water availability exist from Turag River’s distributaries in front of the bank; presence of much big shaded local trees in the village and 83.33% stakeholders think ‘not effective at all’ as non-availability of water (almost dried about 1.5 to 2 feet depth of water remaining. In Study area - 7: Birulia urban wetland, during monsoon season, 36.67% stakeholders think ‘effective resilience’ for cooling effect as maximum availability of water depth in the wetland (nearly 30 feet depth of water availability exist from Turag River’s distributaries in front of the bank during monsoon season; lot of big local shaded trees in the village enable surrounding environment feels cool. 56.67% stakeholders think ‘moderately effective resilience’ as availability of water and 6.67% stakeholders have ‘no idea’.

5.1.1.2.2 Storage Capacity During Heavy Rainfall on Flood Stress of Selected Urban Wetlands

According to study area stakeholder perceptions it was identified that, in Study area - 1: Dhanmondi Lake, 73.33% stakeholders think that this water body has been performing ‘effective resilience’ for storage capacity during heavy rainfall as rain/storm water can store in the lake and 20.0% stakeholders think ‘moderately effective resilience’ as overflow bank areas in monsoon season sometimes and 6.67% stakeholders have ‘no idea’.

In Study area - 2: Gulshan-Baridhara Lake, 80.0% stakeholders think that this water body has been performing ‘effective resilience’ for storage capacity during heavy rainfall as rain/storm water can store in the lake. 16.67% stakeholders think ‘moderately effective resilience’ as can store rain water and 3.33% stakeholders have ‘no idea’.

In Study area - 3: Hatirjheel Lake, 76.67% stakeholders think that this water body has been performing ‘effective resilience’ for storage capacity during heavy rainfall as this water body can store rain water effectively during rainy season; surrounding water also can store by different open pipes and drain in the water body. 10.0% stakeholders think ‘moderately effective resilience’ as no reason for choices and 13.33% stakeholders have ‘no idea’.

In Study area - 4: Ramna Lake, 83.33% stakeholders think that this water body has been performing ‘effective resilience’ for storage capacity during heavy rainfall as effective storage of rain and surface water and 16.67% stakeholders have ‘no idea’.

In Study area - 5: Diabari Bottola Lake, 100.0% stakeholders think that this water body has been performing ‘effective resilience’ for storage capacity during heavy rainfall as rain water and surface runoff store by surface drains and much numbers of storm water pipes normally and do not create any water logging problem in surrounding areas still now, much depth of the lake.

In Study area - 6: Ashulia urban wetland, during summer season, 96.67% stakeholders think that this water body has been performing ‘effective resilience’ for storage capacity during heavy rainfall as no obstruction for storage of water in the wetland (effective natural drainage); as huge low land and 3.33% stakeholders have ‘no idea’. In Study area - 6: Ashulia urban wetland, during rainy season, 100.0% stakeholders think that this water body has been performing ‘effective resilience’ for storage capacity during heavy rainfall as no obstruction for storage of water in the wetland (effective natural drainage).

In Study area - 7: Birulia urban wetland, during summer and rainy season, 100.0% stakeholders think that this water body has been performing ‘effective resilience’ for storage capacity during heavy rainfall as water can easily store in this large water body; enough storage area for rain water.

5.1.1.3 Attribute - 3: 'Contribution for community livelihood'

In (2014), Shimul mentioned, "Ancient history has the proof how a city and its livelihood, economy and recreational growth has taken place around the water bodies over time and how the human life and the balance of nature is dependent on water and water bodies". This attribute tried to find out the current status and existing role on contribution for community livelihood from study area stakeholder perceptions in seven study areas as follows:

5.1.1.3.1 Types of Community Livelihood at Present in Surrounding Seven Urban Wetlands

According to study area stakeholder perceptions it was identified that, in Study area - 1: Dhanmondi Lake, winter and monsoon (both) seasons livelihood are livelihood from much vendors/hawkers activities with various professions, livelihood from angling/sport fishing, livelihood from paddle boating activities, livelihood from different permanent, temporary (big and small) and mobile restaurant's, livelihood from maintenance activities of lake and lake surrounding areas (monitoring, washing, cleaning, security etc.) by DSCC, Local Government authorities, Mothsho Club etc.

In Study area - 2: Gulshan-Baridhara Lake, winter and monsoon (both) seasons livelihood are livelihood from vendors activities with different professions, livelihood from fish cultivation by commercial leasing system, livelihood from maintenance activities of lake and lake surrounding areas (monitoring, washing, cleaning, security etc.) by Local Government authorities and fish cultivation leaser committee etc.

In Study area - 3: Hatirjheel Lake, winter and monsoon (both) seasons livelihood are livelihood from vendors activities with various professions only afternoon time (after 4 pm) of the day (as restricted by the authorities), livelihood from water transport activities, livelihood from some permanent and mobile restaurant activities etc., livelihood from maintenance activities of lake and lake surrounding areas (monitoring, washing, cleaning, security etc.) by Bangladesh Army and DNCC (only for lake surrounding road) etc.

In Study area - 4: Ramna Lake, winter and monsoon (both) seasons livelihood are livelihood from very few vendors activities (totally restricted recently); livelihood from permanent restaurants activities etc.; livelihood from maintenance activities (monitoring, washing, cleaning, security etc.) by PWD (City Division) authorities.

In Study area - 5: Diabari Bottola Lake, winter and monsoon (both) seasons livelihood are livelihood from agricultural activities, livelihood from fish cultivation by commercial leasing system, livelihood from nursery activities, livelihood from paddle boating (for recreation) activities, livelihood from few non-engine boat for recreation, livelihood from vendors activities with various professions, livelihood from open shops activities for selling of wetland based surrounding products (fresh vegetables, milk etc. from local Bou bazar), livelihood from small shops (mudi dokan) activities for local people, livelihood from horse cart activities, livelihood from maintenance activities of lake and lake surrounding areas (monitoring, washing, cleaning, security etc.) by Local Government authorities, fish cultivation leaser committee and RAJUK etc.

In Study area - 6: Ashulia urban wetland, winter season livelihood are livelihood from agricultural activities, livelihood from fishing activities, livelihood from brick manufacturing activities during the dry season (recently banned by Bangladesh Government) etc.; monsoon season livelihood are livelihood from fishing activities, livelihood from water transport activities, livelihood from boating etc.; both seasons livelihood are poultry (duck farming) activities, some vendors activities, few small restaurants for visitors etc.

In Study area - 7: Birulia urban wetland, winter season livelihood is livelihood from agricultural activities, livelihood from fishing activities etc.; monsoon season livelihood are livelihood from fishing activities, livelihood from water transport activities, livelihood from boating etc.; both seasons livelihood are few vendors activities, few small shops for local people etc.

5.1.1.3.2 Types of Crops that Relevant for Agricultural-based Livelihood in Surrounding Seven Urban Wetlands

According to study area stakeholder perceptions, in Study area - 1, 2, 3, and 4 as Dhanmondi Lake, Gulshan-Baridhara Lake, Hatirjheel Lake and Ramna Lake, agricultural activities are totally restricted; in Study area - 5: Diabari Bottola Lake, different crops that relevant for agricultural based livelihood as Bottle gourd (Lau), Colliflower (Ful kopi), Cabbage (Bandha kopi), Papaya (Pepey), Malabar/Indian spinach (Pui shakh), Green Amaranth spinach (Data shakh), Spinach (Palong shak), Red spinach (Lal shak), Corriander (Dhonia) etc. have been growing within both dry and monsoon seasons of the year; in Study area - 6: Ashulia urban wetland, different crops as Boro paddy (28) (Boro Dhan), Tomato (Tomato), Bottle Gourd (Lau), Colliflower (Ful kopi), Water spinach (Kolmi shakh), Red spinach (Lal shak), Radish (Mula) etc. have been growing in the dry season of the year; in Study area - 7: Birulia urban wetland, different crops as Boro paddy (28) (Boro Dhan), Red spinach (Lal shak), Spinach (Palong shak), Colliflower (Ful kopi), Tomato (Tomato), Bottle gourd (Lau), Pumpkin (Kumra), Spice (Morich) etc. has been growing in the dry season of the year.

5.1.1.3.3 Type of Fishes that Relevant for Commercial Fishing-based Livelihood (lease system) in Surrounding Seven Urban Wetlands

According to study area stakeholder perceptions, in Study area - 1, 3, and 4 as Dhanmondi Lake, Hatirjheel Lake and Ramna Lake commercial fishing based livelihood activities are restricted; in Study area – 2: Gulshan-Baridhara Lake, different fishes that mostly relevant for commercial fishing based livelihood as River catfish (Pangash), Tilapia (Tilapia), Catfish (Magur) etc.; in Study area - 5: Diabari Bottola Lake, Bighead carp (Brigade), Chitol fish (Chitol), Rohu (Rui), Catla (Catla), Silver carp fish (Silver carp), Grass carp (Grass carp), Mrigal carp (Mrigal) etc. and Study area - 6: Ashulia urban wetland and Study area - 7: Birulia urban wetland respondent mentioned about natural water fishes mainly.

5.1.1.3.4 Type of Fishes that Much Relevant for Angling/Sport Fishing in Surrounding Seven Urban Wetlands

According to study area stakeholder perceptions, in Study area - 2, 3, 6 and 7 as Gulshan-Baridhara Lake, Hatirjheel Lake, Ashulia urban wetland and Birulia urban wetland there were no information found about type of fishes that much relevant for angling/sport fishing and respondent of Study area - 1, 4 and 5 as Dhanmondi Lake, Ramna Lake and Diabari Bottola Lake mentioned that, Bighead carp (Brigade), Rohu (Rui), Catla (Catla), Tilapia (Tilapia), etc.; Catla (Catla), Rohu (Rui), Tilapia (Tilapia), Bighead carp (Brigade) etc. and Catla (Catla), Rohu (Rui), Bighead carp (Brigade), Grass carp (Grass carp), Mrigal carp (Mrigal) etc. are relevant for angling/sport fishing.

5.1.1.3.5 Type of Natural Water Fishes that Relevant for Livelihood in Surrounding Seven Urban Wetlands

According to study area stakeholder perceptions, in Study area - 1, 2, 3, 4, 5 as Dhanmondi Lake, Gulshan-Baridhara Lake, Hatirjheel Lake, Ramna Lake and Diabari Bottola Lake there were no information found about natural water fishes that relevant for livelihood and respondent of Study area - 6 and 7 as Ashulia urban wetland and Birulia urban wetland mentioned that, Tangra fish (Tangra), Catfish (Magur), Stinging catfish (Shing), Climbing perch (Koi), Khoilsha fish (Khoilsha), Tilapia (Tilapia), River catfish (Boal), Striped snake head (Shole) etc. and Climbing perch (Koi), Stinging catfish (Shing), Catfish (Magur), River catfish (Pangash), Snake head (Taki), Khoilsha fish (Khoilsha), Mola fish (Mola), Dhela fish (Dhela), Puntius fish (Puti) etc. are relevant for natural water fish-based livelihood.

5.1.1.3.6 Types of Vendor's Activities at Present in Surrounding Seven Urban Wetlands

According to study area stakeholder perceptions, in Study area - 1: Dhanmondi Lake**,** different vendors that have been working as Coconut seller, Vegetable seller, Ice cream seller, Chotpoti-fuchka seller, Tea seller, Pan/cigarate seller, Candi flaws seller, Peanut/boot seller, Flower seller, Jhal muri seller, Children's toy seller, Water bottle seller, Velpuri seller, Shooting play activities, Coffee seller, Baloon seller, Winter pitha seller (seasonal), Weight lifting machine activities, Chips seller, Fresh cutting fruits and vegetables seller (as guava/amra/cucumber) seller, Seasonal fruit seller etc.; in Study area - 2: Gulshan-Baridhara Lake**,** Cobbler (shoe color mechanics), Peanut seller, Tea seller, Vegetable seller, Guava seller, Banana seller, Velpuri seller, Flower seller, Boot seller, Coconut seller, Kothbel seller, Jhal muri seller, Cigarate seller, Water bottle seller, Black berry seller, Peanut seller, Chanachur seller, Kamranga seller etc.; in Study area - 3: Hatirjheel Lake**,** Banana seller, Jhal muri seller, Peanut seller, Flower seller, Weight lifting activity, Velpuri seller, Boot seller, Cigarate seller, Chotpoti-fuchka seller, Tea seller, Pan seller, Potato chips seller, Chanachur seller, Different fruit seller etc.; in Study area - 4: Ramna Lake**,** Bottle water seller, Flower seller, Cobbler, Weight lifting machine activity etc.; in Study area - 5: Diabari Bottola Lake**,** Chotpoti-fuchka seller, Jhal muri seller, Peanut seller, Tea seller, Flower seller, Ice cream seller, Velpuri seller, Vegetable seller, Milk seller, Guava seller, Boroi seller, Banana seller etc.; in Study area - 6: Ashulia urban wetland**,** Chotpoti-fuchka seller, Peanut seller, Tea seller, Velpuri seller, Coconut seller etc. and in Study area - 7: Birulia urban wetland, Tea seller, Coconut seller, Banana seller, Peanut seller, Seasonal fruits seller etc.

5.1.1.3.7 Study Area Stakeholder Perceptions According to the Scale of Contribution on Attribute - 3

According to study area stakeholder perceptions, in Study area - 1: Dhanmondi Lake, 76.66% stakeholders think that this water body has been performing 'effective contribution' for community livelihood as good environment for different livelihood activities; a lot of people come in this lake area for recreation day to night, income better during afternoon times normally and Friday, holidays, special days etc.; comparatively good income from different livelihood activities; presence of recreational based fishing (angling); presence of small and big restaurants based livelihood; good economic profit from restaurants based livelihood;

presence of paddle boating livelihood with good economic profit; presence of varieties of hawkers based livelihood; hawkers can bear their family from their livelihood activities in this area; vendors doing their livelihood activities from Hazaribag and Raer Bazar areas normally; much presence of visitors from different places that enhance economic profit; relevant authorities give permission for different livelihood activities in this area; secured place for doing livelihood activities etc. and 23.34% stakeholders think ‘moderately effective contribution’ as regulation by the authorities for livelihood on commercial fishing; no lease system presently by the authorities for commercial fishing (about 10 years after renovation); absence of commercial lease system interrupts much economic profit that could be earned earlier 10 yrs back and this is directly linked to fish quality and quantity; obstructing whole system of fish cultivation; absence of natural water fishes; less and negligible income from angling; angling is only for professional anglers of ‘Mothsho Club’ members (800 taka/chip) and restricted for public use; lack of support from relevant Government organizations on to provide fish lings, medicine and fish food etc. for angling; presence of few unexpected people in the area that hamper livelihood sometimes etc.

In Study area - 2: Gulshan-Baridhara Lake, 13.33% stakeholders think that this water body has been performing ‘moderately effective contribution’ for community livelihood as presence of hawkers-based livelihood; hawkers are allowed in this area; presence of commercial fishing-based livelihood. 56.67% stakeholders think ‘less effective contribution’ as lack of natural water fishes for bad water; for bad water quality, culture fishes (as River catfish (Pangash), Tilapia (Tilapia), Catfish (Magur) etc.) are increasing which have less demand among urban dwellers with less economic profit than local ones (as Rohu (Rui), Catla (Catla) etc.) expensive for fish lease holders and farmers to cultivate fish in bad quality of water; fish farmers have to take much challenges to overcome fish cultivation for bad water quality; financial return is less on commercial fishing for bad water quality of the lake in recent times than before; restricted on water transport, restaurants etc. based livelihood; less income among hawkers than other areas sometimes; sometimes less presence of visitors for bad smell of water surrounding the lake). 23.33% stakeholders think ‘not effective at all’ as less presence of visitors for bad smell of water sometimes in the lake; bad environment for any kind of uses (mainly Badda bank side) and 6.67% stakeholders have ‘no idea’ about the issue.

In Study area - 3: Hatirjheel Lake, 26.67% stakeholders think that this water body has been performing ‘effective contribution’ for community livelihood as presence of water transport, small and big restaurants based livelihood; much economic profit from water transport based livelihood; people enjoy much to travel by water buses in different routes; can go their required places with low costs and less time; livelihood on washing and cleaning of the lake surrounding areas; livelihood on security etc. 46.67% stakeholders think ‘moderately effective contribution’ as less presence of public during bad odor of water causing less income for restaurants based livelihood; if restaurants open the entry door or windows, bad smell of water normally pollute their restaurants environment; fewer neighborhood customers from Hatirjheel area come to the lake surrounding restaurants; presence of some unexpected people in the lake side’s areas hamper livelihood of people sometimes; restricted for vendor based livelihood. 23.33% stakeholders think ‘less effective contribution’ as restricted for vendor-based livelihood for environmental concern (nearly 30 to 40 nos. floating hawkers come after 4 pm and sit outside the lake areas); less income for floating vendors and they have to depend for their livelihood to other areas of the city; food items are expensive for low-income people and 3.33% stakeholders have ‘no idea’.

In Study area - 4: Ramna Lake, 20.0% stakeholders think that this water body has been performing 'moderately effective contribution' for community livelihood as presence of recreational based fishing (angling) for only professional anglers (fishes can catch per year for 3,000-taka ticket cost per day only for anglers); much local varieties of good quality fish availability; good taste of fishes; presence of few restaurant-based livelihood; few vendors are allowed. 13.33% stakeholders think 'less effective contribution' as restricted for public based livelihood activity. 53.34% stakeholders think 'not effective at all' as restriction of vendors for entry in this area and they have been working outside Ramna Park area outside the gate sometimes; vendors have to depend on other areas for their livelihood and 13.33% stakeholders have 'no idea'.

In Study area - 5: Diabari Bottola Lake, 16.67% stakeholders think that this water body has been performing 'effective contribution' for community livelihood as presence of agricultural based livelihood on the bank areas; good crop quality from lake water (lake water have been using after 7 to 8 days for cultivation) and organic fertilizer (cow dung); soil is enough fertile for agricultural livelihood activities; crops can be planted within whole the year round; much economic profit from agricultural activities; presence of commercial fishing based livelihood with much economic profit for fishermen; lake water is good for fish cultivation; much local fish availability for good water; presence of recreational based fishing (angling-open to public) for professional anglers (fishes can be catching in Friday for 2,000 taka ticket cost per chip); presence of nursery based livelihood; presence of boating based livelihood for recreation (paddle boating); presence of vendors based livelihood; authorities allow various professions to do their livelihood activities in the lake areas; good environment for livelihood activities up to 6 pm afternoon. 56.67% stakeholders think 'moderately effective contribution' as people presence is comparatively less, only in friday, saturday, special days etc. people used to visit this place; people come to this area in rainy season than in dry season for much water availability and cool environment in monsoon season; economic profit is less than other areas for less public presence; absence of restaurants, small food shops etc.; lack of security. 26.66% stakeholders think 'less effective contribution' as less presence of visitors with less economic profit from all types of livelihood activities; much lack of security.

In Study area - 6: Ashulia urban wetland, in winter season, 36.67% stakeholders think that this water body has been performing 'effective contribution' for community livelihood as maximum economic profit from agriculture, brick manufacturing work, poultry etc.; maximum local community people depend on agricultural activities; good quality of crops produced from this wetland; wetland soil is much fertile for agricultural activities; effective for poultry farm (as duck farm); maximum profit from brick field (recently banned by Govt.). 46.67% stakeholders think 'moderately effective contribution' as water has been deteriorated from long time, livelihood by agriculture has been declining day by day than before; crop quality and quantity has been deteriorated and declined by over polluted water; crops are affected by various diseases for use of remaining wetland water in dry season sometimes; need to control pests by using external medicine; need to use chemical fertilizer to grow crops; quantity of Boro paddy has been declining than before; economic profit has been declined by agriculture than before; less quantities of small fishes available in remaining wetland water during dry period (as water level is very low and almost dried) that cannot maintain fishing livelihood of community people and fishermen have to depend on adjacent Turag River for fishing that time with very low quality of fishes that time; no Government financial support on agriculture and fishing based livelihood. 10.0% stakeholders think 'less effective contribution' as water is not good for any use in recent times and 6.67% stakeholders have 'no idea'.

In Study area - 6: Ashulia urban wetland, in rainy season, 23.33% stakeholders think that this water body has been performing ‘moderately effective contribution’ for community livelihood as less economic profit from fishing, water transport, boating based livelihood than agriculture. 66.67% stakeholders think ‘less effective contribution’ as fish quality and quantity has been declining day by day than before for over polluted water; less quantity of fishes are available than the past that reflect less economic profit for the local fishermen; less availability of local carp type fishes than before (Rohu (Rui), Catla (Catla) etc. mainly); taste of fishes is not good to eat; bad smell in fishes for polluted water; less demand of wetland fishes among local people as fish quality has been deteriorated by over polluted water; local fishermen cannot maintain their family by catching their fishes as the quality of fishes has been declined with bad smell and bad taste; local people often consume fishes from local market as wetland fish quality deteriorated. 10.0% stakeholders think ‘not effective at all’ as dead water of Turag River is not suitable for any livelihood activities in the wetland at present in this area.

In Study area - 7: Birulia urban wetland, in winter season, 30.0% stakeholders think that this water body has been performing ‘effective contribution’ for community livelihood as maximum economic profit from agriculture; good quality of crops produced from this wetland; wetland soil is much fertile for agricultural activities and 70.0% stakeholders think ‘moderately effective contribution’ as crop quality and quantity has been deteriorated and declined by over polluted water than before; crops are affected by various diseases for use of remaining wetland water and Turag River water in dry season; have been declining crops yield quality at present time by using wetland water; need to control pests by using external medicine; economic profit has been declined by agriculture than before; many local farmer has been shifted their livelihood from agriculture to other livelihood activities for less economic profit; no Government financial support on agriculture and fishing based livelihood.

In Study area - 7: Birulia urban wetland, in rainy season, 16.67% stakeholders think that this water body has been performing ‘moderately effective contribution’ for community livelihood as less economic profit from fishing, water transport, boating based livelihood; varieties of local fishes are available still now but declining than before; fishes are growing and increasing breeding here naturally. 73.33% stakeholders think ‘less effective contribution’ as this water body situated Turag River floodplain, polluted water hampering directly fishing activities; less quantity of fishes are available than the past that reflect less economic profit for the local fishermen; less availability of local carp type fishes than before; fish quality has been deteriorated by over polluted water; taste of fishes is not good to eat; bad smell in fishes for polluted water; less demand of wetland fishes among local people as fish quality has been deteriorated by over polluted water; local fishermen cannot maintain their family by catching their fishes as the quality of fishes has been declined with bad smell and bad taste; many local fishermen has been shifted their livelihood from fishing to other livelihood activities (as engaged in small business, worker in garments, factories, industries etc.) with time; seepage of oil from water transports that has been polluting wetland water. 6.67% stakeholders think ‘not effective at all’ as wetland water that mixed with Turag River is completely destroyed by dying factories and other industries for any kind of use now and 3.33% stakeholders have ‘no idea’.

5.1.1.3.8 Existing and Potential Livelihood Activities in Selected Study Areas

Selected urban wetlands have been contributing different direct (wetland resource dependent livelihood) and indirect livelihood activities presently according to study area stakeholder perceptions that described as follows:

In Study area - 1: Dhanmondi Lake, direct livelihood has not been contributing as ‘livelihood by agricultural activities’ and ‘livelihood by commercial fish cultivation activities’ as restricted by Dhaka South City Corporation (DSCC) within surrounding the lake and no commercial leasing system; contributing as ‘livelihood by angling (sports/recreational fishing) activities’ (with negligible income from angling); have not been contributing as ‘livelihood by water transport activities’ (as restricted by the Government authorities within the lake and no commercial leasing system and not implemented yet (Government order passed already in 2021 to connect Dhanmondi Lake, Hatirjheel Lake and Gulshan-Baridhara Lake by water transport recently)); contributing as ‘livelihood by paddle boating activities for recreation’ with yearly net income about 36,50,000 taka (approx.) [around 36 lacs]. Indirect livelihood have been contributing as ‘livelihood by big permanent restaurant activities’ with yearly net income about 73,00,000 to 91,25,000 taka (approx.) [around 73 to 91 lacs] and ‘livelihood by small temporary restaurant activities’ with yearly net income about 36,50,000 to 54,75,000 taka (approx.) [around 36 to 55 lacs]; contributing as ‘livelihood on cleaning and washing the lake surrounding areas’; contributing as ‘livelihood on security activities of lake surrounding areas’; contributing as some ‘small shops for tea/cigarette/cake’ with yearly net income about 4,32,000 taka (approx.) [around 4 lacs]; and ‘vendor activities by different professions’ with yearly net income about 1,44,000 to 5,40,000 taka (approx.) [around 1 to 5 lacs] etc. (400 to 1500 taka/day)

In Study area - 2: Gulshan-Baridhara Lake, direct livelihood have not been contributing as ‘livelihood by agricultural activities’ (as restricted by Local Government authorities within surrounding the lake and no commercial leasing system (Badda side’s fish lease holders and local community people has been cultivating different fruit trees, vegetables and local crops personally on the Badda side slope of the lake premises, but that is not commercial)); contributing as ‘livelihood by commercial fish cultivation activities’ with yearly net income about 10 to 13 Lacs taka (approx.) for one lease holder; have not been contributing as ‘livelihood by water transport activities’ (as restricted by the Government authorities within the lake and no commercial leasing system and not implemented yet). Indirect livelihood has been contributing as ‘livelihood on cleaning and washing the lake surrounding areas’; contributing as some ‘small shops for tea/cigarette/cake’ and ‘vendor activities by different professions’ with yearly net income about 1,08,000 to 5,40,000 taka (approx.) [around 1 to 5.4 lacs] etc. (300 to 1500 taka/day)

In Study area - 3: Hatirjheel Lake, direct livelihood have not been contributing as ‘livelihood by agricultural activities’ (as restricted by Bangladesh Army within surrounding the lake and no commercial leasing system); not been contributing as ‘livelihood by commercial fish cultivation activities’ (as restricted by Bangladesh Army, no commercial leasing system, restriction of catching and cultivation any fishes in the lake); not been contributing as ‘livelihood by angling (sports/recreational fishing) activities’ (as restricted by Bangladesh Army); contributing as ‘livelihood by water transport activities’ with yearly net income about 9,12,50,000 to 10,95,00,000 taka (approx.) [around 9 to 11 crore] etc. Indirect livelihood have been contributing as ‘livelihood by big permanent restaurant activities’ with yearly net income about 6,00,000 taka (approx.) [around 6 lacs]; contributing as ‘livelihood by small temporary restaurant activities' with yearly net income about 7,00,000 taka (approx.) [around 7 lacs]; contributing as 'livelihood on cleaning and washing the lake and surrounding areas' with yearly net income about 48,000 to 60,000 taka (approx.); contributing as 'livelihood on security activity' and 'vendor activities by different professions' with yearly net income about 1,08,000 to 3,60,000 taka (approx.) [around 1 to 3.6 lacs] etc. (300 to 1000 taka/day)

In Study area - 4: Ramna Lake, direct livelihood have not been contributing as 'livelihood by agricultural activities' (as restricted by Public Works Department (PWD) within surrounding the lake and no commercial leasing system); not been contributing as 'livelihood by commercial fish cultivation activities' (as restricted by commercial fish cultivation activities, no lease system commercially exist by Public Works Department (PWD)); contributing as 'livelihood by angling (sports/recreational fishing) activities'; not been contributing as 'livelihood by water transport activities' (as restricted by the PWD authorities within the lake and no commercial leasing system and not implemented yet); not been contributing as 'livelihood by boating activities for recreation'(as restricted by the PWD authorities) etc. Indirect livelihood have been contributing as 'livelihood by big permanent restaurant activities' with yearly net income about 1 Crore 27 Lacs taka (approx.); contributing as 'livelihood on monitoring, maintenance and cleaning'; contributing as 'livelihood on cleaning and washing the lake surrounding areas' with yearly net income about 1,98,000 taka (approx.) [around 2 lacs]; contributing as 'livelihood on security activities of lake surrounding areas' with yearly net income about 1,44,000 taka (approx.) [around 1.5 lacs] and 'vendor activities by different professions' with yearly net income about 72,000 to 1,44,000 taka (approx.) [around 72 thousand to 1.5 lacs] etc. (200 to 400 taka/day)

In Study area - 5: Diabari Bottola Lake, direct livelihood have been contributing as 'livelihood by agricultural activities' with yearly net income (for 1 bigha land) about 3,00,000 to 4,00,000 taka (approx.) [around 3 to 4 lacs]; have been contributing as 'livelihood by commercial fish cultivation activities' with yearly net income about 4 to 5 Lacs taka (approx.) for one lease holder; contributing as 'livelihood by angling (sports/recreational fishing) activities'; contributing as 'livelihood by boating activities for recreation' for non-engine boat with yearly net income about 2,73,750 taka (approx.) [around 3 lacs] and for paddle boat with yearly net income about 9,12,500 taka (approx.) [around 9 lacs] etc. Indirect livelihood have been contributing as 'livelihood on cleaning and washing of the lake and surrounding areas'; 'livelihood on security activities'; 'nursery activity' with yearly net income about 1,44,000 to 2,16,000 taka (approx.) [around 1.5 to 2 lacs]; 'easy bike activity' with yearly net income about 2,88,000 taka (approx.) [around 3 lacs]; 'horse cart activity' with yearly net income about 1,80,000 to 2,88,000 taka (approx.) [around 2 to 3 lacs]; 'small shop for tea/cigarette' 3,60,000 to 4,32,000 taka (approx.) [around 3.6 to 4 lacs]; and 'vendor activities by different professions' with yearly net income about 90,000 to 3,60,000 taka (approx.) [around 90 thousand to 3.6 lacs] etc. (250 to 1000 taka/day)

In Study area - 6: Ashulia urban wetland, direct livelihood have been contributing during winter season as 'livelihood by agricultural activities' for boro paddy cultivation (for 1 bigha land) with yearly net income about 30,000 to 40,000 taka (approx.) [around 30 to 40 thousands] for one lease holder, for tomato cultivation with yearly net income about more than 1,00,000 taka (approx.) [around 1 lacs] for one lease holder; for other vegetables cultivation with yearly net income about 50,000 to 60,000 taka (approx.) [around 50 to 60 thousands] for one lease holder etc.; have been contributing during monsoon season as 'livelihood by fishing activities' with yearly net income about 9 to 10 Lacs taka (approx.); contributing as 'livelihood by boating activities for recreation' for boat with yearly net income about 90,000 taka (approx.) [around 90 thousands]; contributing as 'livelihood by poultry activities (duck farming)' with yearly net income about 60,000 to 70,000 taka (approx.) [around 60 to 70 thousands]; contributing as 'livelihood by brick manufacturing activities' with yearly net income about 1,26,000 taka (approx.) [around 1 lacs] for one worker etc. Indirect livelihood has been contributing as 'vendor activities by different professions' with yearly net income about 1,80,000 to 4,32,000 taka (approx.) [around 2 to 4.30 lacs] etc. (500 to 1200 taka/day)

In Study area - 7: Birulia urban wetland, direct livelihood have been contributing during winter season as 'livelihood by agricultural activities' for boro paddy cultivation (for 1 bigha land) with yearly net income about 20,000 to 22,000 taka (approx.) [around 20 to 22 thousands] for one farmer, for tomato cultivation with yearly net income about more than 80,000 taka (approx.) [around 80 thousands] for one farmer; have been contributing during monsoon season as 'livelihood by commercial fishing activities' with yearly net income about 70,000 to 80,000 taka (approx.) [around 70 to 80 thousands] for one fisherman; contributing as 'livelihood by boating activities for recreation' for boat with yearly net income about 1,00,000 taka (approx.) [around 1 lacs]. Indirect livelihood has been contributing as 'small shop owner' and 'vendor activities by different professions' with yearly net income about 1,44,000 to 5,40,000 taka (approx.) [around 1.4 to 5.4 lacs] etc. (400 to 1500 taka/day)

5.1.1.4 Attribute - 4: 'Adequacy of the policy regime'

This attribute tried to find out the current status and existing role on Government policies from study area stakeholder perceptions in seven study areas as follows:

5.1.1.4.1 Study Area Stakeholder Perceptions According to the Scale of Contribution on Attribute - 4

According to study area stakeholder perceptions it was identified that, in Study area - 1, 2, 5 and 6 as Dhanmondi Lake, Gulshan-Baridhara Lake, Diabari Bottola Lake and Ashulia urban wetland, 100.0% stakeholders do not have any level of knowledge of the policy, in Study area - 3: Hatirjheel Lake, only 3.33% stakeholders and in Study area - 4: Ramna Lake, only 6.67% stakeholders listened about 'Poribesh Ain' these days, but they do not know whether these Government laws are adequate or not and in Study area - 7: Birulia urban wetland, only 3.33% stakeholders heard about 'Joladhar Ain', but they do not know about the meaning and adequacy of these laws.

5.1.1.5 Attribute - 5: 'Local acceptance and credibility of the role of relevant institutions'

This attribute tried to find out the current status and existing role on the role of relevant institutions from study area stakeholder perceptions in seven study areas as follows:

5.1.1.5.1 Relevant Institutions on Seven Selected Urban Wetlands

According to study area stakeholder perceptions it was identified that, in Study area - 1: Dhanmondi Lake, relevant institutions' are DSCC, DWASA, DoE, Fisheries Department, Local Government Institutions (Ward Commissioner, Councilor etc.), 'Mothsho Club' (Shoukin Mothsho Shikari Shomiti for angling) etc.; in Study area - 2: Gulshan-Baridhara Lake, relevant institutions' are RAJUK, Local Government Institutions (Ward Commissioner, Councilor etc.), DNCC etc.; in Study area - 3: Hatirjheel Lake, relevant institutions' are RAJUK, Bangladesh Army, DNCC, DoE etc.; in Study area - 4: Ramna Lake, relevant institutions' are PWD (City Division, Arboriculture Division, EM Division), Fisheries Department etc.; in Study area - 5: Diabari Bottola Lake, relevant institutions' are RAJUK, Local Government Institutions (Ward Commissioner, Councilor etc.) etc.; in Study area - 6: Ashulia urban wetland, Local Government Institutions as Union Parishad (UP), Paurashavas, Chairman, Secretary, members etc.; in Study area - 7: Birulia urban wetland, Local Government Institutions as Union Parishad (UP), Paurashavas, Chairman, Secretary, members etc.

5.1.1.5.2 Role of Relevant Institutions on Seven Selected Urban Wetlands

5.1.1.5.2.1 Study area - 1: Dhanmondi Lake

DSCC - has been working on overall main implementation and maintenance of this water body, main lease authority, has been working for lake and lake surrounding maintenance; waste material collection etc. DSCC staff everyday cleans the lake surrounding areas (land areas).
DWASA - has been working on overall drainage construction.
DoE - Water testing.
Fisheries Department - Authorities purchase fish lings, medicine etc. from this department if required.
Local Government Institutions (Ward Commissioner etc.) - Coordination and implementation authority. People have to get permission from Commissioner and Police for doing their livelihood activities in this lake area.
'**Mothsho Club' (Shoukin Mothsho Shikari Shomiti) (Local organization)** - working for fisheries on angling activities. 'Mothsho Club' staff everyday cleans the lake (water areas).

5.1.1.5.2.2 Study area - 2: Gulshan-Baridhara Lake

RAJUK - has been working on overall construction and management, main lease authority.
Local Government Institutions (Ward Commissioner etc.) - main authority at local level; co-ordinate with main Govt. organizations; for co-ordination of commercial leasing system of fish cultivation and other issues etc.
DNCC - has been working for lake adjacent road construction and maintenance; waste material collection etc.

5.1.1.5.2.3 Study area - 3: **Hatirjheel Lake**

RAJUK - has been working here on overall construction and development, main lease authority.
Bangladesh Army - has been working on strict maintenance and overall management of this urban water body.
DNCC - waste materials collection and cleaning from lake side walk way and road.
DoE - Water testing sometimes.

5.1.1.5.2.4 Study area - 4: **Ramna Lake**

Public Works Department (PWD) - has been working on this water body for proper maintenance and overall management of this urban water body.
Fisheries Department - have limited responsibility, water testing and observation when lake water found bad in quality sometimes.

5.1.1.5.2.5 Study area - 5: **Diabari Bottola Lake**

RAJUK - Main authority for this water body related construction, maintenance and management (ex. as walkway, bank protection, drainage and other issues), main lease authority (have been given leased to different local stakeholders for overall maintenance and management). RAJUK will plant trees, gardens, construct shops, restaurants, hotels etc. in this area in future.
Local Government Institutions (Ward Commissioner etc.) - Coordination and implementation authority. (For cleaning the lake water, local lease holders of fish cultivation have been cleaning the lake frequently.)

5.1.1.5.2.6 S**tudy area - 6**: **Ashulia urban wetland**

Local Government Institutions as Union Parishad (UP) etc. - With very limited responsibility, Sometimes UP agricultural officers provide local people agricultural seeds and fish lings, suggestions etc. to local people if required.

5.1.1.5.2.7 Study area - 7: **Birulia urban wetland**

Local Government Institutions as Union Parishad (UP) etc. - With very limited responsibility, UP agricultural officers provide agricultural seeds and fish lings, suggestions etc. to local people sometimes.

5.1.1.5.3 Study Area Stakeholder Perceptions According to the Scale of Contribution on Attribute - 5

According to study area stakeholder perceptions it was identified that, in Study area - 1: Dhanmondi Lake, 53.33% stakeholders have acceptance and credibility of the role of relevant institutions as Dhaka South City Corporation (DSCC) that has been performing 'effective contribution' on this water body according to them as good maintenance on lake and surrounding area; created good environment for the public use; authorities allow various professions to do their livelihood activities in the lake areas safely; authority every day cleans the lake and lake surrounding area in early morning; much staffs appointed from DSCC for working in this lake area that enhance livelihood of many people. 43.34% stakeholders have acceptance and credibility of the role of same relevant institutions with ‘moderately effective contribution’ as lack of proper maintenance by the relevant authorities for pollution control; lack of water quality improvement; lack of security for entry of few unexpected people sometimes; local people do not get any support from Government organizations on angling activities and 3.33% stakeholders have ‘no idea’.

In Study area - 2: Gulshan-Baridhara Lake, 23.33% stakeholders have acceptance and credibility of the role of relevant institutions as RAJUK, Local Government Institutions (LGI) etc. that has been performing ‘effective contribution’ on this water body according to them as trying to do their relevant works; good co-ordination on commercial fish cultivation activities and security. 46.67% stakeholders have acceptance and credibility of the role of same relevant institutions with ‘moderately effective contribution’ as much lack of proper maintenance by the relevant authorities for pollution control; water still in poor condition; local people do not get any support from Government sectors directly on commercial fish cultivation and water quality improvement at all. 13.33% stakeholders have acceptance and credibility of the role of same relevant institutions with ‘less effective contribution’ as water is not good; need more control and 16.67% stakeholders have ‘no idea’.

In Study area - 3: Hatirjheel Lake, 86.67% stakeholders have acceptance and credibility of the role of relevant institutions as Bangladesh Army that has been performing ‘effective contribution’ on this water body according to them as strict maintenance, monitoring and implementation; trying to do their relevant works much effectively; good beautification of the lake area. 6.67% stakeholders have acceptance and credibility of the role of same relevant institutions with ‘moderately effective contribution’ as need to improve water by the relevant authorities; lack of security for entry of few unexpected people sometimes (improving); some lack of safety (improving) and 6.67% stakeholders have ‘no idea’.

In Study area - 4: Ramna Lake, 63.33% stakeholders have acceptance and credibility of the role of relevant institutions as Public Works Department (PWD) that has been performing ‘effective contribution’ on this water body according to them as effective maintenance for lake and park beautification and improvement; have been taken good steps on angling activities; proper maintenance by the relevant authorities for pollution control; have been taken good steps on water quality improvement. 20.0% stakeholders have acceptance and credibility of the role of same relevant institutions with ‘moderately effective contribution’ as lack of security (improving); lack of manpower for maintenance and security (improving) and 16.67% stakeholders have ‘no idea’.

In Study area - 5: Diabari Bottola Lake, 10.0% stakeholders have acceptance and credibility of the role of relevant institutions as RAJUK, (LGI) etc. that has been performing ‘very effective contribution’ on this water body according to them as doing good work. 66.67% stakeholders have acceptance and credibility of the role of same relevant institutions with ‘effective contribution’ as effective maintenance of water pollution; effective development of lake and lake side areas; allow various professions to do their livelihood activities in the lake areas; will develop more in future. 10.0% stakeholders have acceptance and credibility of the role of same relevant institutions with ‘moderately effective contribution’ as less presence of visitors for much lack of security; fish farmers do not get any support from fisheries departments or other organizations for fish resource improvement and development and 13.33% stakeholders have ‘no idea’.

In Study area - 6: Ashulia urban wetland, 80.0% stakeholders have acceptance and credibility of the role of relevant institutions as UP that has been performing ‘less effective contribution’ on this water body according to them as maximum land is local people’s private land or leased land; as UP do not deal with any conservation and maintenance works with their own with very limited capacity and responsibility; local people do not get any financial support from different organizations on wetland conservation issue etc. UP have other responsibility), 13.33% stakeholders have ‘no acceptance’ as maximum land is local people’s private land and they have to do their own work related any conservation issue and 6.67% stakeholders have ‘no idea’ about the issue.

In Study area - 7: Birulia urban wetland, 16.67% stakeholders have acceptance and credibility of the role of relevant institutions as UP that has been performing ‘moderately effective contribution’ on this water body according to them as doing good work for the village people. 63.33% stakeholders have acceptance and credibility of same relevant institutions with ‘less effective contribution’ on this water body according to them as maximum land is local people’s private land; UP have very limited capacity and responsibility on conservation and management issue; no financial support from different organizations to local people for management of wetland rather they do by themselves if necessary etc. 6.67% stakeholders have ‘no acceptance’ as land owner has been doing their own agricultural activities etc. and 13.33% stakeholders have ‘no idea’ about the issue.

5.1.2 Challenges of Urban Wetland Management and Use according to the Urban Wetland Sustainability Framework (UWSF) Model – 1 of Selected Urban Wetlands that Extracted from Study Area Stakeholder Perceptions

This section discussed about the challenges of urban wetland management and use according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' of selected urban wetlands that extracted from study area stakeholder perceptions that followed the second objective and the second research question that have been developed in this research.

5.1.2.1 Attribute - 1: 'Contribution for biodiversity conservation and enhancement'

Study area - 1: Dhanmondi Lake

Water is not good in recent days for surrounding pollution that have a threat on local aquatic species; visitors and public pollute the lake areas; waste disposal from surrounding domestic and commercial set up transmitted to the lake water during rainy season.

Study area - 2: Gulshan-Baridhara Lake

Water is not suitable for fishes and other aquatic animals to live for surrounding waste pollution; every year fishes found dead floated on the top surface of the water body for bad quality of water (mainly in winter); bad smell of water found especially in winter season; surrounding pollution from domestic, industrial, clinical, construction waste and waste water from both sides of residential areas as Gulshan and Badda and from surrounding commercial areas destroying this water body; direct and indirect sewerage pipe line connection from Gulshan and Badda areas to the water body; polluted water mixed with wetland water in rainy season and degrading the water of this wetland.

Study area - 3: Hatirjheel Lake

Fishes cannot find often, observed very less in quantity as water is not good; water gets polluted and blackish by waste disposal from Kawron bazar fish market area and Rampura area mainly, defecation pollution, bathing, waste water from surrounding drain etc. disposed to this lake; surrounding polluted water mixed with wetland water in rainy season and degrading the water of this wetland.

Study area - 4: Ramna Lake

Fishes sometimes found dead floated on the water in monsoon season as surrounding commercial area's polluted water mixed with this water body; bank erosion sometimes observe.

Study area - 5: Diabari Bottola Lake

Some floating waste comes from surrounding area in rainy season; storm water pipes and surface runoff outfall can be harmful in future for convey of pollution in the lake when urban development will increase; pollution by public sometimes; fish farmers have been using medicine (5 to 6 nos. packets for one day) for cleaning of lake water; need to provide additional fish food often in the lake water by fish farmer; costing of fish cultivation is high as its required to provide medicine and fish food in the water; people cannot use lake water for drinking; absence of water plants as water lily, lotus etc.; very less plants, shaded trees, flowers plants are available surrounding the water body (RAJUK have planned to plant these trees in coming future).

Study area - 6: Ashulia urban wetland

Water quality degradation for pollution as industrial, construction waste, chemical waste and waste water etc. (from dyeing and other factories and industries of Ashulia, Dhaka city, Gazipur and Tongi areas); Ashulia wetland surrounded by dead water of Turag River during monsoon and dry season; absence of shaded trees surrounding the water body.

Study area - 7: Birulia urban wetland

Pollution from industrial, domestic, construction waste and waste water; polluted water of Turag River mixed with this flood plain in rainy season and degrading the water of this wetland; absence of shaded trees surrounding the water body (presence of trees only in village areas).

5.1.2.2 Attribute – 2: 'Resilience of urban wetlands to face the challenges of climate change impacts'

5.1.2.2.1 Cooling Effect During Summer on Heat Stress of Selected Urban Wetlands

Study area - 1: Dhanmondi Lake

Cool during afternoon time mainly in summer season.

Study area - 2: Gulshan-Baridhara Lake

Non availability of big shaded trees in Badda bank side; day time much hot in summer season; feel cool during night time.

Study area - 3: Hatirjheel Lake

Cool during monsoon season mainly than summer.

Study area - 4: Ramna Lake

Much feel cool during afternoon time and monsoon season.

Study area - 5: Diabari Bottola Lake

In summer season, between afternoon (normally after 5 pm) to night time of the day feel comparatively cool for presence of water than day time; absence of big shaded trees on the banks.

Study area - 6: Ashulia urban wetland

Water almost dried in winter; absence of big shaded trees on the banks and surrounding areas.

Study area - 7: Birulia urban wetland

Water almost dried in winter; absence of big shaded trees on the banks and surrounding areas.

5.1.2.2.2 Storage Capacity During Heavy Rainfall on Flood Stress of Selected Urban Wetlands

Study area - 1: Dhanmondi Lake

Overflow bank areas in monsoon season sometimes.

Study area - 2: Gulshan-Baridhara Lake

Improper drainage connection in some areas surrounding the water body.

Study area - 3: Hatirjheel Lake

Improper drainage connection in some areas surrounding the water body.

Study area - 4: Ramna Lake

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Study area - 5: Diabari Bottola Lake

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Study area - 6: Ashulia urban wetland

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Study area - 7: Birulia urban wetland

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5.1.2.3 Attribute – 3: 'Contribution for community livelihood'

Study area - 1: Dhanmondi Lake

Regulation by the authorities for livelihood on commercial fishing; no lease system presently by the authorities for commercial fishing (about 10 years after renovation); absence of commercial lease system interrupts much economic profit that could be earned earlier 10 yrs back and this is directly linked to fish quality and quantity that obstructing whole system of fish cultivation; absence of natural water fishes for water quality degradation; need to provide external medicine, fish food, labor for maintenance and cleaning yearly for declining water quality on fishing with high investment cost; less and negligible income from angling for low paid people as fish farmers, guards etc.; angling is only for professional anglers of 'Mothsho Club' members (800 taka/chip) and restricted for public use; lack of support from relevant Government organizations on to provide fish lings, medicine and fish food etc. for angling; presence of few unexpected people in the area that hamper livelihood sometimes; wetland dependent resource -based livelihood is restricted for public.

Study area - 2: Gulshan-Baridhara Lake

Less presence of visitors for bad smell of water sometimes in the lake; bad environment for any kind of uses (mainly Badda bank side); have to use external medicine, fish food, labor for maintenance and cleaning yearly for declining water quality on fishing with high investment cost; wetland dependent resource-based livelihood is restricted for public; lack of support from relevant Government organizations on to provide fish lings, medicine and fish food etc. for fish cultivation activities.

Study area - 3: Hatirjheel Lake

Restricted for vendor-based livelihood for environmental concern (nearly 30 to 40 nos. floating hawkers come after 4 pm and sit outside the lake areas); less income for floating vendors and they have to depend for their livelihood to other areas of the city; food items of restaurants are expensive for low-income people; wetland dependent resource-based livelihood is restricted for public.

Study area - 4: Ramna Lake

Restricted for public based livelihood activity; wetland dependent resource-based livelihood and other indirect livelihood activities is restricted for public.

Study area - 5: Diabari Bottola Lake

Less presence of visitors with less economic profit from all types of livelihood activities; need to use external medicine, fish food, labor for maintenance and cleaning yearly for fish cultivation with high investment cost; need to provide small fishes yearly with high investment cost for cultivation from other districts as Rangpur, Dinajpur etc.; much lack of security; lack of support from relevant Government organizations on to provide fish lings, medicine and fish food etc. for fish cultivation activities; wetland dependent resource-based livelihood is restricted for public.

Study area - 6: Ashulia urban wetland

In winter, water is not good for any use in recent times that interrupting wetland dependent resource-based livelihood recently than the past; economic profit have been declining than the past; wetland dependent resource-based livelihood is restricted for public, only allowed for local community village people who are the owners of the land and lease holders of wetland resources; in monsoon, dead water of Turag River is less suitable for any livelihood activities in the wetland mainly fishing at present in this area; lack of support from relevant Government organizations for agriculture and fishing activities.

Study area - 7: Birulia urban wetland

During winter and monsoon, wetland water that mixed with Turag River is completely destroyed by dying factories and other industries for any kind of use now that interrupting wetland dependent resource-based livelihood recently than the past; economic profit have been declining than the past; fishing livelihood activities have been seriously hampering for dead water of Turag River at present in this area in monsoon season; lack of support from relevant Government organizations for agriculture and fishing activities; wetland dependent resource-based livelihood is restricted for public, only allowed for local community village people who are the owners of the land and lease holders of wetland resources.

5.1.2.4 Attribute – 4: Adequacy of the policy regime

Lack of awareness on policies and adequacy of policy regime among study area stakeholders.

5.1.2.5 Attribute – 5: 'Local acceptance and credibility of the role of relevant institutions'

Study area - 1: Dhanmondi Lake

Lack of proper maintenance by the relevant authorities for pollution control; lack of water quality improvement; lack of some security for entry of few unexpected people sometimes; local people do not get any support from Government organizations on angling activities.

Study area - 2: Gulshan-Baridhara Lake

Water is not good, need more control on mainly pollution.

Study area - 3: Hatirjheel Lake

Need to improve water by the relevant authorities; lack of security for entry of few unexpected people sometimes (improving); some lack of safety (improving).

Study area - 4: Ramna Lake

Lack of security (improving); lack of manpower for maintenance and security (improving).

Study area - 5: Diabari Bottola Lake

Less presence of visitors for much lack of security; fish farmers do not get any support from fisheries departments or other organizations for fish resource improvement and development.

Study area - 6: Ashulia urban wetland

Maximum land is local people's private land and they have to do their own work related any conservation issue; do not get any support from Government organizations for wetland resource conservation, improvement and development and livelihood issues.

Study area - 7: Birulia urban wetland

Land owner has been doing their own agricultural activities; negligible support from Government organizations for wetland resource conservation, improvement and development and livelihood issues.

5.1.3 Recommendations for Future Improvement on Sustainable Conservation and Management of Selected Urban Wetlands according to the Urban Wetland Sustainability Framework (UWSF) Model – 1 Extracted from Study Area Stakeholder Perceptions

This section discussed about the recommendations that have been identified during the field survey according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' of selected urban wetlands that extracted from study area stakeholders' perceptions that followed the fifth objective and the fifth research question that have been developed in this research.

5.1.3.1 Attribute - 1: 'Contribution for biodiversity conservation and enhancement'

In Study area - 1: Dhanmondi Lake, study area stakeholders' think that, lake and surrounding environment should be more clean and maintain properly every day; water should be safe for aquatic species to live mainly as fishes; if pollution will be less in future, much variety of local fishes can live here; public should not pollute the water by throwing waste in the water etc.

In Study area - 2: Gulshan-Baridhara Lake, study area stakeholders' think that, local species of fishes already declined here, if water qualities will be good, much varieties of those species can be return here as before which is less in quantity now; sewerage connection line from both sides of Gulshan and Badda sides areas should be stopped soon; to stop dumping of sewage wastes on the both bank sides of the water body etc.

In Study area - 3: Hatirjheel Lake, study area stakeholders' think that, water should be clean, odorless in future; drain should be constructed surrounding the water body so that polluted water can divert through other ways without disposal in this water body; to stop Kawron bazaar pollution immediately; to stop surrounding waste and waste water entry from Rampura and other sides of the lake etc.

In Study area - 4: Ramna Lake, study area stakeholders' did not say anything about this attribute.

In Study area - 5: Diabari Bottola Lake, study area stakeholders' think that, lake and surrounding environment should be more clean.

In Study area - 6: Ashulia urban wetland, study area stakeholders' think that, if water will be good in future, much varieties of fishes and other aquatic species will live here in rainy season mainly; to stop harmful waste and waste water from surrounding industries, factories etc. for sustain of aquatic species in the water body (as fishes have been dyeing) etc.

In Study area - 7: Birulia urban wetland, study area stakeholders' think that, water should be treated at first.

5.1.3.2 Attribute - 2: 'Resilience of urban/sub-urban water bodies to face the challenge of climate change impacts'

5.1.3.2.1 Cooling Effect During Summer on Heat Stress of Selected Urban Wetlands

In Study area - 1, 3, 4 and 7 as Dhanmondi Lake, Hatirjheel Lake, Ramna Lake and Birulia urban wetland, study area stakeholders did not say anything about this 'cooling effect' on this attribute. In Study area - 2: Gulshan-Baridhara Lake, study area stakeholders' think that, to plant big shaded trees on Badda bank side as Gulshan bank sides by relevant authorities. In Study area - 5: Diabari Bottola Lake, study area stakeholders' think that, by planting of big shaded trees on the banks and surrounding areas that may reduce the heat in summer season. In Study area - 6: Ashulia urban wetland, study area stakeholders' think that, to plant big shaded trees on both bank sides (road side areas).

5.1.3.2.2 Storage Capacity During Heavy Rainfall on Flood Stress of Selected Urban Wetlands

Study area stakeholders' think that, drainage connection should be improved surrounding the water bodies areas for passing the rain water easily.

5.1.3.3 Attribute - 3: 'Contribution for community livelihood'

In Study area - 1: Dhanmondi Lake, study area stakeholders think that, water should be safe from pollution disposal; commercial fish cultivation by lease system should be introduced as soon as possible as before for good maintenance and production of lake fishing and livelihood; small local water boat can be introduced for livelihood and short communication etc.

In Study area - 2: Gulshan-Baridhara Lake, study area stakeholders think that, water should be improved at first, then many local fishes can live here, many people can bear their livelihood by this fishing activities with much economic profit; other varieties of livelihood can be performed effectively (as much vendors, small shops, restaurants etc.) if water smell of the lake can be reduced; local water boat can be introduced for livelihood etc.

In Study area - 3: Hatirjheel Lake, study area stakeholders think that, should control pollution and improve water quality for presence of public to increase more livelihood activities; security should be ensured more by the authorities for presence of more visitors and to work in this area etc.

In Study area - 4: Ramna Lake, study area stakeholders did not say anything about this attribute.

In Study area - 5: Diabari Bottola Lake, study area stakeholders think that, if people presence will increase, the livelihood of people will also increase in future; security should be more ensured by the authorities to increase visitor presence and to work in this area etc.

In Study area - 6: Ashulia urban wetland, study area stakeholders think that, if water will improve, fish and crops production also good in future, income will increase more, livelihood of local people will increase as well; if water will be good, local fishermen will get their appropriate economic return by fishing in both seasons as before etc.

In Study area - 7: Birulia urban wetland, study area stakeholders think that, bad water should be improved.

5.1.3.4 Attribute - 4: 'Adequacy of the policy regime'

In all study area stakeholders did not say anything about this attribute, as they do not have any definite knowledge about Government policies and regulations.

5.1.3.5 Attribute - 5: 'Local acceptance and credibility of the role of relevant institutions'

In Study area - 1: Dhanmondi Lake, study area stakeholders think that, should more concern about the lake environment and pollution; should implement commercial lease system on fishing for more economic profit and livelihood; relevant Government organizations should provide proper financial support for angling as to provide fish lings, medicine, fish food etc. with free or low cost; there is a problem on security for few unexpected peoples in this area sometimes and authorities should be more concern about this issue etc.

In Study area - 2: Gulshan-Baridhara Lake, study area stakeholders think that, need to clean the water of this lake by relevant authorities immediately; Government organization should provide financial support for commercial fish cultivation etc.

In Study area - 3: Hatirjheel Lake, study area stakeholders think that, water should be improved by relevant authorities as soon as possible.

In Study area - 4: Ramna Lake, study area stakeholders think that, security should be improved more by the authority; drinking water point should be introduced; presence of few unexpected people sometimes should be controlled; walkway should be developed besides the bank of water body; low-cost restaurants and small food corner should be developed for public etc.

In Study area - 5: Diabari Bottola Lake, study area stakeholders think that, security should be ensured by the relevant authorities for wide presence of local people and visitors; it will be good for everyone if proper financial support from Government can be ensured on agricultural and fish cultivation activities mainly etc.

In Study area - 6: Ashulia urban wetland, study area stakeholders think that, different Government organizations should treat the over polluted water for maximum economic profit from agriculture and fishing-based livelihood; to stop Turag River pollution by dyeing factories and other industries; to stop all types of waste dumping on the bank sides of the water body by the authorities etc.

In Study area - 7: Birulia urban wetland, study area stakeholders think that, Government authorities should take initiatives to save this wetland as soon as possible; authorities should clean the polluted water of Turag River immediately by stop pollution from industries and others sources mainly etc.

(II) Institutional Stakeholder Expert's Perceptions

This section discussed the results of institutional stakeholder expert's perceptions on semi-structured interview with thirteen nos. purposive samples and analyzed with five-point Likert scale according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' in seven study areas.

5.1.2 Current Scenario and Existing Role of Selected Urban Wetlands According to the Urban Wetland Sustainability Framework (UWSF) Model – 1

This section prefers the current scenario and existing role of selected urban wetlands according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' from institutional stakeholder expert's perceptions that followed the first objective and the first research question that have been developed in this research.

5.1.2.1 Attribute - 1: 'Contribution for biodiversity conservation and enhancement'

2.20% institutional stakeholder experts think 'effective contribution' as in Ramna Lake, overall, about 80 to 90% water of this water body is good in water quality. There are many fruit trees as mango, jackfruit, jam, jamrul, boroi, date, banana, jam (black berries), palm, jongli lotkon, dumur, milon (rare species, fruits as mango but sour, have only four nos. trees of this species), kathbadam, pesta, kazu etc.; medicinal plants as nim, arjun, amloki, boira, horitoki etc.; wooden trees as shegun etc.; flowery trees as krishnochura, jarul, kodom, sonalu, raintree, hibiscus, bokul, krishnochura, radhachura, nagalindom, kurchim, black sea, hizol, alvesia, kushumchaya, kodom, chatim, bot, cristuan, panthopodok, udaipaddha, okush, cassia saima, cassia japanika, balam, udelplay (very beautiful), oxyquick (bloom in the rainy season), pagore, oshokh, bonna flower, shapla (few, planted many seeds in the lake, but cannot grow much, only one place in the lake is exist, but in coming future authorities will try to plant shapla and poddo aquatic plants) etc. are available. Water plants as kochuripana, topapana, khudipana naturally exist in this water body, but authority clean everyday according to their rules. Water submerged leaves from different trees and plants are clean everyday by our cleaning staffs. There are no harmful water-based plants that can destroy whole aquatic systems. This lake is 25 to 30 ft in depth and water does not dry easily. There is always standing water found in this water body. For this reason, there are enough fishes are available in this Ramna Lake water body as rui (normally weight as 12 to 13 kg), catla (normally weight as 20 to 25 kg), Big Head Carp (Australian), shing, tilapia, magur, tatkini, silver carp, pangash (gher pangash), puti, chingri, shole, taki etc. are available in this urban water body. Fishes are breeding naturally in this water body, authorities do not give any food for these fishes and these fishes consume natural food from natural habitat of aquatic systems. Even authorities do not give any medicine for fish breeding as well. Different diverse aquatic snakes as ghora snakes (do not have poison) and others, tortoises, crores of snails and oysters/mussels. Different birds as bok, tia, shalik, wakh birds (have 2 to 4 nos.) and some of water birds (as pankouri etc.) are available and in Dhanmondi Lake, after re-development the scenario of this urban water body already improved more than before. From different researches on water quality test of this water body had seen that this water body have adequate water quality parameter standard value within limit in Dhaka city. Different aquatic flora and fauna are living in this water bodies. Different type of fishes, aquatic species and plants added good biodiversity protection as well. 5.49% stakeholders think 'moderately effective contribution' as still now working in some areas but declining; 54.93% stakeholders think 'less effective contribution' as in Dhaka city each water body is higher risk in condition. Industrial, domestic, clinical and other waste materials and waste water has been degrading all water bodies from long time that deteriorated the water quality of these water courses. There are two main reasons behind this situation, these are, firstly, urban pollution and secondly, loss of habitat etc. Pollution is very high and biodiversity is very low recently. Inadequate sewerage connection is another issue for less contribution for biodiversity conservation of these water bodies. Different types of aquatic flora, fauna, as plants, fishes, reptiles etc. have been living in these selected water bodies, but in course of time these species are disappearing day by day. This wide diversity of species is very much important for ecological function of any water body. But in Dhaka city, for unplanned urban development and population pressure this situation getting most terrible now. It’s very much difficult for fishes or any other aquatic species to live in these water bodies recently. Biodiversity is not all about only fishes, it is also a system of biotech as soil, species, fishes, water, edge etc. at all, recently water bodies of Dhaka city have been failing this system of an ideal water body. These urban water bodies in Dhaka city are important for two functions, firstly for natural drainage function and secondly these have been working as a lung or natural cleansing system to conserve the biodiversity. But these functions have been losing recently at all. The system of water bodies is at least existing, but not functional and under threat for different issues. Different researches from different institutions and organizations found that there is high level of variation in declining the water quality parameters and almost fail the standard limit. For an example, a study was made by Mr. Badruzzaman, professor, BUET on the effect of pollution of Dhanmondi lake water where existence of heavy metal was found with the fishes in the lake. As an example, a good system observes in Hatirjheel Lake, it could have been easily turn it to if water will be clean, then different types of fishes could live, even birds cannot come to these lakes as much noise and disturbance, much pollution. In the point of view of water quality, Hatirjheel is in a very bad state. There conservation of bio-diversity is at stake, in terms of ranking - bio-diversity is seriously affected there. Hatirjheel had planned and designed for working on auto filtration system, but excess sewage pollution has been breaking this auto filtration capacity and cannot work properly. The result is water quality is getting very bad. As an example, we can see in North Calcutta, India, no Effluent Treatment Plant (ETP) exist there rather they have a big wetland, water have been getting filter naturally out of Calcutta city to Sundarban. As an example, water of Ashulia and Birulia wetland in past was crystal-clear along with availability of plenty of sweet water fish. But now a day’s intrusion of dirty water from the river Turag has been polluting the wetland as a whole. There are plenty of brick fields in this area for which fertility of land has seriously been affected. Nearly 20 years back, only agricultural lands in this area and obviously the paddy lands are the most suitable growing centers for fish lings. Many research found Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and other parameters have been failing the standard level of water quality. There is very less scientific researches, documents and records have been conducted till to date for this issue on ‘biodiversity conservation and enhancement’ of urban water bodies in Dhaka city. So, it is very much difficult to say something clearly about this issue. But different organizations and institutions are trying to do their best to resolve this issue. There is no enough water test performed on documentation of biodiversity that we can summarizes all aquatic species easily. Maximum industries, factories do not follow and use of Effluent Treatment Plant (ETP) and are discharging their waste water in to the water bodies without waste water treatment. Much pollution has been existing in Balu and Turag River water, dyeing industries have been discharging polluted waste and waste water directly to the water bodies without any kind of Effluent Treatment Plant (ETP). River Dhaleswari also same in situation now, Tannery industry of Hazaribag shifted to Savar now, but there is only one central effluent plant that is not working, one retention pond that also not in proper use, so waste water stock and finally discharge to this Dhaleswari River without any type of treatment. Government has been ordered to install Effluent Treatment Plant (ETP) in every industry, but there are several reasons these are not following properly by authorities. The result is, water quality of these water bodies declining day by day. Urbanization is a topmost negative impact that hinders the proper functions of these water bodies. In Ashulia and Birulia urban water bodies, which are situated on the flood plain of Turag River have been destroying by industrial pollution mainly. Encroachment is common in these areas to fill up water retention areas recently. There is also lack of initiatives towards biodiversity and ecosystem conservation of these water bodies in the capital. Lack of 'community involvement' towards aquatic biodiversity improvement is another big issue for improper conservation. Public people do not have any knowledge and ideas about these issues at all. Urban land use changed after migration of people from other places in Bangladesh in Dhaka city (population have increased nearly 25% up to yr 1999), that's why there started a huge transformation of biodiversitification within these urban water bodies. For this reason, when these wetlands had shrinkages day by day, biodiversity had totally gone. Therefore, unplanned land use is a reason for this situation. First Structural Plan had made in the year of 1997, in which located the land of water bodies, but that was not working later, so we had lost many water bodies from that time and biodiversity also had lost from that time. Now we have negligible amount of water bodies in Dhaka city. All these hampering the biodiversity and ecological roles of these water bodies recent times in the capital. Still now there is pollution in Dhanmondi Lake by public people that need to resolve. In Ashulia wetland, different types of big trees and plants cannot grow in this water body as water is present during six months a year. There are less birds are observed in Ashulia as water is polluted. Once there was a time, when the water of Ashulia water body very good in quality, but recent years and day by day that situation completely changed and water found very much polluted here by different issues for agriculture and fishing development. Pollution through surrounding garment and chemical industries discharge waste and waste water into the Turag River flood plains and this Ashulia water body is also within this Turag River floodplain, have a direct connection to Turag. Turag River water carries different water transports and vessels that have been polluting water area of Ashulia flood plain by oil seepage. Brick field is a source of black smoke production in Ashulia that hampers to grow big trees. Encroachment is another reason that has been reducing this Ashulia water body area as well. Previously, there were no treatment systems in garments and industries in Ashulia, but after installing treatment options, may be these cannot work properly, so that situation not improve still now. Water is polluted and with bad odor enough still now in Ashulia. Waste and waste water also come from Dhaka city in Ashulia from Tongi, Gazipur areas. Local people of Ashulia affected by touching this polluted water as water borne diseases as diarrhea, skin diseases etc. There is much mosquito's growth found during monsoon periods in Ashulia. In Birulia, in dry winter season, water of this water body has been found dark black in color with very bad smell. Day by day situation getting worst and degrading and destroying by waste and waste water (chemical mix water) by different industries that surrounding this Birulia water body. Surrounding garments and factories discharge waste water into Birulia water body daily. Gazipur and Tongi industries waste water are responsible for this worst situation in Birulia. There are lot of pipe connection from industries to Birulia water body to discharge and disposal of waste water without any kind of treatments that degrading this water. Once there were sanitation connection lines between household to water body and this situation already improved in Birulia. 4.39% think 'not effective at all' as serious water quality degradation by industrial and other pollution, urbanization, encroachment, lack of pollution awareness among urban dwellers etc. and 32.99% stakeholders have no idea or didn't response.

5.1.2.2 Attribute - 2: 'Resilience of urban water bodies to face the challenge of climate change impacts'

5.1.2.2.1 Cooling Effect During Summer on Heat Stress of Selected Urban Wetlands

2.20% institutional stakeholder experts think 'effective resilience' as in Ramna Lake, every day about 1000 nos. peoples come to this area morning and afternoon (for jogging, walking, passing leisure time and recreation) to get a pleasant environment, to get a natural cool breeze to breath. City people who come here said always, 'we get our lives back to come here.' So, obviously it is a one of the best places to enjoy, feeling comfort. As this water body is surrounding by vast green trees and vegetations everybody naturally feels cooler than other areas of the city even in the dry season from heat problem. As Dhanmondi Lake is a beautiful place to enjoy for the people in Dhaka city. Many people from different areas gather here for recreation morning to night. It is also a nice and effective gathering place in special days as 'Pohela Boishakh, Eid days etc. People feel very comfortable and cooling environment coming close to this water body; 9.89% think 'moderately effective resilience' as in Dhanmondi Lake, encroachment is negligible here, lack of trees on the banks in some areas. 38.46% think 'less effective resilience' as all selected water bodies proved at risk or in a threat already on resilience to climate change impacts. Daily temperatures of the city are increasing gradually that raising the urban heat island effects these days in Dhaka city. Heat resistance capacity of these urban water bodies has been gradually decreasing. Normally urban wetlands are as lung for the Dhaka city that useful to breathing and to control the climate change impacts. But on the based on 'urban cooling effect', cooling system of urban wetland has been declining for over paved area in the city as heat produces by the concrete. Much Particulate Matter (PM) deposition by infrastructure development and urbanization in the city; air pollution by vehicle, industries etc. that enhance climate change impacts in the city. If proper urban wetlands could exist in Dhaka city, this city could not get hot and different diseases as asthma, heart diseases etc. could not affected to urban peoples. There are very less scientific reports conducted for this issue in our country still now. Lack of trees on the banks of Ashulia water body. Birulia water body cannot work properly presently. It is very much difficult for the city to cope with the recent 'climate change impacts' for these water bodies. If we cannot conserve and manage these water bodies in coming days as soon as possible, it will hamper our quality of life at all in future. So, all these water bodies demand proper sustainable management for their new life in Dhaka city that had lost already. 15.38% think 'not effective at all' as water bodies are in a threat, lack of conservation and management etc. and 34.07% stakeholders have no idea or didn't response.

5.1.2.2.2 Storage Capacity During Heavy Rainfall on Flood Stress of Selected Urban Wetlands

4.40% institutional stakeholder experts think 'effective resilience' as in Ramna Lake during rainy season, excess water from the rain can pass into this lake for water storage within few hours of time. This water body can support during drought situation accordingly (as this water body is not dry in summer season as expected to be). This water body can also support different water disasters that happen these days. As by re-development of Dhanmondi Lake by DSCC and other organizations, flood situation in this lake areas now resolved already. Ashulia and Birulia water body can store enough rain water during monsoon season and can accumulate surrounding overflowed water during the same time. These water bodies can work 100% in 'effective' way rain water preservation; 8.80% think 'moderately effective resilience' as encroachment is negligible in Dhanmondi Lake, water holding capacity already decreased by siltation in maximum water bodies etc. 37.36% think 'less effective resilience' as during flood water bodies have been receiving solid and other wastes from surrounding land areas, water bodies get siltation problems. Water areas and depth of water channels gradually decreased from actual dimensions day by day. These days maximum water bodies have been encroached by land grabbers, has been narrowing water courses, for these reasons water holding capacity already decreased, during flood this situation is very worst. Disasters as flood and other disasters resilience also declining. These water bodies have been losing internal connectivity in recent times. For climate change impact, heavy rainfall occurs within a short duration in monsoon in Dhaka city. If there was sufficient capacity to store monsoon rainfall run-off as well as proper drainage system, then the problem of flooding in the city area would be reduced to a great extent as experiencing now days. As an example, country boats ply the inundated roads of Shantinagar areas during monsoon as the drainage systems have almost been collapsed. With a small rainfall, water always accumulates at Mirpur, Dhanmondi Road No. 27 and at different places of the city areas as the marshy lands which acted as reservoir of monsoon water in past are almost filled up creating water logging in the city. Normally there are two reasons for flooding in Dhaka city - first when outside flood water of the surrounding rivers/canals enter in to the city; Polders have been construction to control intrusion of flood water in to the city. The second one is the drainage of water from the city area. In the past flood water is used to reach naturally up to Kallayanpur but now a days we have destroyed the natural drainage system of the wetlands by building flood control embankments for rapid urbanization. At present the existence of marshy lands are almost nil for which the water retention capacity has been reduced drastically. Sustainable capacity of the water bodies has been reduced. The canals/khals have become narrow and their water retention capacity has also been reduced. Those are gradually becoming blocked, water cannot drain out through those canals, creating an adverse and negative environment in the city. The DND bundh area is an example of such an adverse situation. The land inside the DND polder is comparatively low. Embankment has been constructed surrounding the area to control intrusion of outside monsoon water in to the polder. Rain-fall run-off inside the polder area follows through the interconnected canals and reaches to the Singrai point from where accumulated water discharges to the canals outside the polder with the help of pumps. There are three nos. of pumps at Singrai point, one for normal rainfall, another when there is heavy rainfall and the 3rd one is in reserve to operate in adverse situation. Flood is very common disaster in the city every year. These wetlands can accumulate flood water with a huge volume. These water bodies can support extreme drought situation in any city by holding water in dry period and recharge the ground water aquifer in monsoon period for drinking water consumption. But climate change is putting additional stress on these water bodies in the city in recent times. Reducing trend of these wetlands through encroachment by filling up of water bodies by land grabbers is very common in Dhaka city, which have been reducing the areas of urban wetlands in the city. There are several researches by different institutions and authors that identified overall wetland areas reduction study by GIS software defining urban wetlands status in different years. From those studies we can see a huge transformation of wetlands areas that has been declining in the Dhaka city. For this reason, flood water retention areas during monsoon season have been declining these days. Water drainage capacity has been reducing during flood season by lack of connection between rivers, canals, wetlands etc. in the city. Water logging take place maximum areas in Dhaka city. Siltation of wetlands bed reduces water heights of these urban wetlands also. For water retention capacity, drainage problem will create the fill up of these urban wetlands; overall retention capacity has been decreasing; for this reason, drainage systems have been overloading; for under design of these drainage systems, water has been overflowing in Dhaka city; less capacity of drainage system have been observed recently; lack of proper design of drainage system in Dhaka city; so, resilience of climate change impacts has been degrading at all etc. 15.38% think ‘not effective at all’ as all selected water bodies proved at risk already and 34.06% stakeholders have no idea or didn’t response.

5.1.2.3 Attribute - 3: ‘Contribution for community livelihood’

4.40% institutional stakeholder experts think ‘effective contribution’ as Ashulia and Birulia water bodies have been playing a high agricultural value during dry period of the year. High fishing value during rainy season of the year respectively. These values can return high economic profit to the urban dwellers as well. Dhanmondi Lake urban water body has much vendor’s activity in the city than other water courses. It is a good example of livelihood development and gaining financial economic profit for city dwellers as this water body is almost conserved. Different activities of vendors are open in this water body that added a wide range of livelihood development of economic profit for public people. They bear their family by doing these activities in lake side areas; 9.89% think ‘moderately effective contribution’ as Ashulia water body has good contribution in winter season by agricultural development and brick manufacturing and by fishing in rainy season. There are two main types of land use systems exists generally, one private land owners and land by leasing system lease holders (lease for agriculture growth etc.). Among these two types of systems, private land ownership of local people is more than lease holders. Three types of main livelihood systems have been developed by local people here, one is agriculture based and second is fishing based and third is by brick manufacturing. There are several types of crops and vegetables that have been growing on this water body. Fodder cultivation for animals also has a good economic profit on this water body. Agriculture based livelihood have lease systems here, but in case of fishing, there is no lease systems here, everybody can catch fishes during monsoon season here. Normally, local fishermen have been catching fishes in this water body. Water transport (as boat, engine-based troller etc.) for recreation and for small business all are maximum by private owners. This area also has many brick fields and people doing topmost livelihood development by these brick manufacturing works, by gaining lot of economic profit than agriculture and fishing, many people are engaged by employment generation through these brick fields etc. In Birulia wetland, except River Turag, all lands’ ownership is ‘private land owners (becti malicana)’ in this water body. Nearly six months there is dry season. At this time of the year (ashin mash in Bengali), this water body is almost dried and different agricultural development takes place by mainly land owners (private land) and few lease holders. Dry time, soil get fertile by alluvial soil (poli mati) with good soil capacity and different types of crops as Boro paddy (4 to 6 months of the year), tomatoes, pumpkins, lau, lal shak, mula shak etc. have been growing by local farmers. There is lease system exists on Boro paddy cultivation but not on vegetables cultivation normally. During rainy season of nearly six months (start from july and ashar in Bengali month) this scenario almost changed. This water body stored by rain water that time and different abundant of fishes as tilapia, gher er pangash, rui, katla, mrigel, silver carp and small fishes have been catching in this water body by local fishermen. Fishes are growing and increasing breeding here naturally. Fishes are not growing here with lease systems. This water body is open for local people for fishing here (without any ticket systems). 59.34% think ‘less effective contribution’ as presently the ‘livelihood development’ is in a very critical state. The livelihood has been destroyed mainly for two reasons, the first one is for ‘urbanization’ and the second one is for ‘agricultural development’. Livelihood situations are now almost changed in these water bodies by encroachment, uncontrolled pollution etc. There is lot of restriction in urban context for proper livelihood activities. There has been less dependency on urban wetlands livelihood among urban dwellers in Dhaka city. Negligible number of fishes has been found in these urban wetlands recently. There are very few people who have been consuming urban wetlands fishes in Dhaka city. These urban water bodies have a wide value for livelihood development in any city if these can be properly conserved. But recently these water bodies cannot perform ‘community livelihood’ (as gaining economic profit from fishing, agriculture or others etc.) at higher level and effectively for urban dwellers. Tourism based livelihood system has grown for very less peoples, but that is not open to all (public) peoples, example as in Dhanmondi Lake vendors’ activities. But if the overall environment will good, this tourism-based livelihood system could enhance more for this lake. 30 to 40 years back the Burganga River was the major fishing points in Dhaka city where plenty of Hilsha fish and other small fishes were available. Thousands of fishermen used to catch fishes there in the past. A large number of fishermen also used to catch fish in Ashulia wetland, still there are some but the quality has been reduced drastically due to pollution in water. In Ramna Lake, there is strict regulation by the Government (PWD mainly) for banned agricultural development besides the bank of water body, hunting, collecting of aquatic plants and other species from water etc. in this water body for pollution prevention. Fishing is also restricted here by the Government (PWD mainly) all the year round for public. Only fish can be catching for 4 nos. Friday and 4 nos. Saturday within one month per year for 3000 taka ticket cost per day from morning 6 am to evening 6 pm that deposit to the Government fund for angling. There is only one month time (4 Friday and Saturday) permit within in a year for catch fishes by professional angler people only (not open to everyone). PWD authorities leased the restaurants for food maintenance and recreational purposes. There is a big restaurant and a cafeteria in the lake side area. Different delicious foods are available there and much employee (30 to 35 nos.) has been working on it for food services (recently closed and planned for a new coffee shop in coming future). There are strict rules from the authorities not to enter any vendor in this water body area. Only water seller is legally permit to entry, as there is less drinking water source point inside the lake premises. But sometimes flower seller enters without notice. If in future potable water sources and services will be established, these water seller vendors also may be restricted. But recently all livelihood activities are restricted here. In Ashulia water body, this year crops have not grown as expected. Local people did not purchase any vegetables, paddy and fishes from market in the past, but for present situation it is very difficult to get these for livelihood development from this wetland. Once fishes grown from this water body is of full of taste and abundance, but recent times these fishes are not suitable for eat. Different types of fishes are available during rainy season (4 to 6 months). Fishermen cannot bear their family by catching their fishes as the quality of fishes have declined with bad smell and bad taste. In Birulia water body, farmers use rest of the water (with low depth) for growing crops that time, but this water is not good for vegetables to grow. These crops get various diseases by using this water and have been declining crops yield quality. Once this water was good for livelihood development as agriculture and fishing, even we also used to drink this water without any kind of treatment once here with good taste. But recent years that condition almost changed completely by surrounding waste and waste water contamination. During joar-vata fishes are not died actually, they died for surrounding waste and waste water pollution and seepage of oil from water transports. Fishes found here with bad smell, people normally cannot consume (eat) these fishes as the qualities of fishes are too low with bad smell and taste. Poor fishermen catch these fishes normally and tried to sell in the near market, but as these fishes are not in good quality, people do not want to purchase these from the market, that’s why fishermen often purchase good quality fishes from Upazila market and sell those. These fishes cannot consume by the family of themselves too for bad quality. There is no income UP get from this water body etc. and 26.37% stakeholders have no idea or didn’t response.

5.1.2.4 Attribute - 4: 'Adequacy of the policy regime'

5.1.2.4.1 Government Policies that Extracted from Institutional Stakeholder Expert's Perceptions

-RAJUK has been trying to work their best on different acts and rules as 'Town Improvement Act'; 'Open space and water body conservation Act, 2000'; 'Park, wetland and open spaces conservation Act, 2002' and 'Environment conservation rules, 1995-2010' etc.

-Department of Environment (DoE) also has different policies, rules, acts and regulations on these urban and sub-urban water bodies for conservation and restoration respectively as 'National Environment Policy, 2018'; 'The Bangladesh Environment Conservation Act, 1995'; 'The Bangladesh Environment Conservation Rules, 1997'; 'National Biodiversity Assessment and Programme of Action 2020, 2014'; 'The Bangladesh Climate Change Strategy and Action Plan (BCCSAP), 2009'; 'The Brick Burning (Control) (Amendment) Act, 2001'; 'Ozone Depleting Substances (Control) Rules, 2004' etc.

-DWASA has different Government National water rules and laws in different years and trying to follow these rules and regulations respectively.

-PWD authority has been maintained a very strict rules and regulations every time to save Ramna Lake.

-Others Acts - yr.2000; Rules - yr.2005; Water law; Environment laws; Jolmohol policy, Environment conservation acts, Water policies; Water acts; Joladhar Songrokkon Aine etc. has been working on these water bodies.

-Ashulia/Birulia water body has 'Joladhar Songrokkon Ain'.

5.1.2.4.2 Institutional Stakeholder Experts Perceptions According to the Scale of Contribution on Attribute - 4

40.69% institutional stakeholder experts think 'effective contribution' of policy regime as there are enough Government policies, rules, regulations in different year that adopted by the Government of Bangladesh and those are adequate; 38.46% think 'moderately effective contribution' as there are sufficient policies, acts, rules etc. in the country and 20.85% stakeholders have no idea or didn't response.

5.1.2.5 Attribute - 5: 'Local acceptance and credibility of the role of relevant institutions'

5.1.2.5.1 Relevant Institutions' that Extracted from Institutional Stakeholder Expert's Perceptions

According to institutional stakeholder expert's perceptions following are some of relevant institutions that were identified as RAJUK, PWD, DoE, DSCC/DNCC, Department of Fisheries (DoF), BFDC, DWASA, BWDB, BIWTA, BIWTC, Nodi Rokkha Commission, Bangladesh Army, Local Government Institutions (LGIs), Union Parishad-Ashulia/Birulia, CEGIS, SPARSO, Civil Society Organizations and NGOs as BAPA, BELA and POBA and social media etc.

5.1.2.5.2 Role of Relevant Institutions' that Extracted from Institutional Stakeholder Expert's Perceptions

RAJUK - have the leading role to play on selected urban water bodies in the capital for planning, implementation and overall development, RAJUK is presently working on Gulshan-Baridhara Lake urban water body re-development, worked on Hatirjheel Lake urban water body re-development, Diabari Bottola Lake urban water body development and working on Ashulia urban water body. RAJUK are doing their work based on different lease system to several private companies' area basis respectively. Walkway of water bodies, demarcation, urban forestry's bank of the water bodies etc. are among development area of RAJUK.

Public Works Department (PWD) - have been working as strict maintenance and overall management of this Ramna Lake urban water body from long time. As (PWD) is doing good job to save this water body from long time and have the top most priority and acceptance among people. This PWD have three division that has been working, these are: (i) City Division (to implement and development of infrastructures inside Rama Park and water body and for cleaning, maintenance and overall development of aquatic products as fishes and other aquatic species); (ii) Arboriculture (to maintain trees, plants, herbs etc. surrounding the lake side's areas and within park premises); (iii) EM Division (to maintain electric power within whole areas of Ramna Park and Lake).

Department of Environment (DoE) - is responsible for monthly monitoring of 'water quality' in Dhanmondi Lake, Gulshan-Baridhara Lake, Hatirjheel Lake urban water bodies and Turag River flood plain especially.

DSCC/DNCC - has been doing a good job with on Dhanmondi Lake urban water body. DSCC with collaboration of other organization are trying to do more work connecting this water body. There are two committees as 'management committee' and 'consultant committee' in DSCC for development work in Dhaka city. Within this 85.6 acre area, 56.0 acre is lake area, storm water drainage management newly developed, from 2005 year sewerage line already closed, outside sewerage drainage and roadside pipe drainage connection closed by the authority. There are 90 nos. security people that have been appointed here, this area is divided into seven sectors with lease systems, for common space maintenance on cleanliness and safety, it is divided into eight sectors. Fisheries on this lake are responsible by 'Shoukhin Motsho Shikari Shomity'. DNCC has been working on Gulshan-Baridhara and Hatirjheel Lake management.

Department of Fisheries (DoF) - if there is any problem occurs regarding water quality or fishes, PWD inform Fisheries Department usually for treatment. Department of Fisheries also work with PWD on some maintenance works about Dissolved Oxygen (DO) test when the water found polluted much. Department of Fisheries has been responsible to provide fish lings of different fish into Ramna water body one time in monsoon season of the year. This organization also has been working on Dhanmondi Lake. In Ashulia water body, fish lings supplied by the Fisheries Department of Bangladesh to Upazila office level and Upazila office employees come to give these fish lings (rui pona) into this water almost two years back.

BFDC - once worked on Gulshan Lake to provide fish lings and give suggestions on improvement of fish diversity into the water. That time BFDC used to provided carp type fishes lings into that lake as rui, katla etc. But in present time BFDC are not providing any fish lings to this lake and not working presently on any of selected lake within long time. BFDC are working now on Captai Lake in Rangamati.

DWASA - have been working on storm water drainage management actually, built storm and sewer network drainage systems for the city and in selected urban water bodies' areas (as Dhanmondi Lake, Hatirjheel Lake areas etc.), also have built cross drainage system as well in those study areas.

BWDB - (dealing with flood issues), have high role to play and to be more concern on these selected urban water bodies issues in the capital.

BIWTA and Nodi Rokha Comission - has been working on water bodies encroachment prevention recently (Turag, Buriganga Rivers etc.) and this is a good work for the conservation of urban and sub-urban wetlands in the capital and this is very good initiatives from Government, a big hope for all. BIWTA has been working on Birulia water body for dredging work maintenance sometimes by the higher authorities of BIWTA. This organization is responsible for whole Turag River flood plain. They are dealing with water transports and landing stations management of this area as well.

BIWTC - has been working on Hatirjheel water transport management.

Bangladesh Army - has been working on Hatirjheel re-development, overall management and maintenance etc.

Local Government Institutions (LGI) - some examples of Local Administration departments have good initiatives as Tangail River case and Ariel Kha River re-treatment etc.

Ashulia and Birulia Union Porishod (UP) - Union agricultural officers and assistant agricultural officers who are working with UP (their office in UP building) maintaining some works as giving crops seeds (they get seeds from Upazila office at Savar centrally by the higher authorities of Government) to farmers for growing crops, giving suggestions as required to farmers or take steps on agriculture connecting if required etc. with very limited responsibility.

Other authorities in Birulia - some authorities came from Ministry for observation some years ago, we gave a report on 'this water body gets bad situation in dry winter season and this water body needs to conserve and save urgently'.

CEGIS - is a GIS based organization that has been working on different researches of these urban water bodies. This is also a good initiative for the urban water bodies' conservation and management.

SPARSO - working on these urban wetlands (map-based GIS improvement).

Civil Society Organizations and NGOs as BAPA, BELA and POBA etc. - are doing well on these urban water issues. Have been working for public awareness involvement as well. POBA is working actually on 'movement works', 'people awareness works' etc. by arranging different seminars and meetings.

Social media - also doing good role on water issues, have been working good on 'social shaming' that means how to influence mass peoples and these media is good for awareness.

5.1.2.5.3 Institutional Stakeholder Experts Perceptions According to the Scale of Contribution on Attribute - 5

4.23% institutional stakeholder experts think 'Bangladesh Army' with 'effective contribution' of acceptance and credibility (on Hatirjheel management mainly) as has been performing 'good management and maintenance'; 22.23% think 'RAJUK, PWD, DoE, DSCC/DNCC, Department of Fisheries (DoF), BFDC, DWASA, BWDB, BIWTA, BIWTC, Nodi Rokkha Commission, Local Government Institutions (LGIs), CEGIS, SPARSO, Civil Society Organizations and NGOs as BAPA, BELA and POBA and Social Media' are performing with 'moderately effective contribution' of acceptance and credibility respectively as 'these organizations may be trying to do their best, but output cannot reach in level', 'lack of coordination among all relevant organizations to handle every work on development', 'lack of management by relevant authorities', 'lack of manpower on maintenance issues still now' etc.; 7.23% think Union Parishad (UP) (for Ashulia/Birulia) with 'less effective contribution' of acceptance and credibility as 'UP cannot doing any direct work on water body conservation'; 'UP has very limited power to solve different problems connecting water bodies'; 'there are neither NGOs nor environment departments are working on these water bodies'; 'UP cannot tackle all pollution connecting water bodies' etc.; 9.38% think 'not effective at all' as need to more concern and 56.93% stakeholders have no idea or didn't response.

5.1.3 Challenges of Urban Wetland Management and Use according to the Urban Wetland Sustainability Framework (UWSF) Model – 1 of Selected Urban Wetlands that Extracted from Institutional Stakeholder Expert's Perceptions

This section discussed about the challenges of urban wetland management and use according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' of selected urban wetlands that extracted from institutional stakeholder expert's perceptions that followed the second objective and the second research question that have been developed in this research.

(1) For Attribute - 1: 'Contribution for biodiversity conservation and enhancement', main challenges of urban wetland management and use are identified as wetlands water quality degradation through human activities and by natural interventions, interrupting species diversity and ecological function of urban wetlands, destruction of habitat, affecting wetland species existence, endangered of wetland species day by day, fish mortality, affecting ideal water body criteria, interrupting natural drainage function and natural cleansing system of urban wetlands, failing the standard limit of maximum water quality parameters, lack of community involvement for biodiversity conservation, lack of awareness among public, endangering human health, unplanned urban development, unplanned land use, reduction of water retention areas by encroachment, over population pressure etc.

(2) For Attribute - 2: 'Resilience of urban water bodies to face the challenge of climate change impacts', main challenges of urban wetland management and use on 'cooling effect' are increase of over paved area in the city, increase of daily temperatures in the city day by day, raising the urban heat island effects, reduction of heat resistance capacity of these urban wetlands, serious air pollution, Particulate Matter (PM) deposition in the atmosphere, affecting human health and quality of urban life, lack of trees in water bodies areas, unplanned urban development, shrinkages of water areas etc.

(3) For Attribute - 2, main challenges of urban wetland management and use on 'storage capacity during heavy rainfall' are unplanned urban development, losing internal connectivity of these water bodies, encroachment and filling by land grabbers, narrowing of water courses, reduction of water retention capacity, reduction of sustainable capacity of urban wetlands, siltation, reduction of water holding capacity, reduction of water depth, interrupting natural drainage system, overloading of drainage systems, less capacity of drainage system, water logging, hampering functioning of main hydrological role for climate change impacts etc.

(4) For Attribute - 3: 'Contribution for community livelihood', main challenges of urban wetland management and use are identified as lot of restrictions for livelihood activities in urban context, limited access of tourism-based livelihood, less dependency on urban wetlands livelihood, uncontrolled pollution, less availability of wetland fishes, negligible consumption of urban wetlands fishes, negligible economic profit from urban wetland resource-based livelihood, interrupting fishing and agriculture-based livelihood, degradation of cultivated crops and fish quality for wetland bad water quality, reduction of crops yield, severe fish mortality, agricultural development, unplanned urban development, encroachment etc.

(5) For Attribute - 4: 'Adequacy of the policy regime', main challenges of urban wetland management and use on policy regime are lack of proper implementation/enforcement of policies still now exists in water sectors for sustainable management, lack of awareness on policies, lack of management, lack of coordination among authorities, lack of political commitment, rules are respectively less, need to be improving more, lack of implementation of rules, lot of gaps between laws and strict enforcement, lack of following policies in effective way by different organization and peoples who are responsible for these urban water bodies, lack of following connecting laws actually on Ashulia and Birulia water bodies, lack of following properly Acts - Yr.2000 and rules - Yr.2005 along with Water law and Environment laws, over population is the main hindrance for the management of these urban wetlands in and around Dhaka city, lack of systems, overlooking 'Joladhar Songrokkon Aine' on maximum urban wetland management issues etc.

(6) For Attribute - 5: 'Local acceptance and credibility of the role of relevant institutions', main challenges of urban wetland management and use on the role of relevant institutions are lack of awareness on valuation of water bodies, lack of coordination among all relevant organizations, lack of maintenance and management by relevant authorities, lack of community involvement and empowerment, lack of adequate secondary transfer stations for disposal of solid waste in the city, lack of manpower on maintenance issues, lack on water connecting planning by the higher authorities from the beginning in Dhaka city, lack of integrated water resource based management, lack of adequate pollution measures by implementation of policies, lack of local level management etc.

5.1.4 Recommendations for Future Improvement on Sustainable Conservation and Management of Selected Urban Wetlands according to the Urban Wetland Sustainability Framework (UWSF) Model – 1 Extracted from Institutional Stakeholder Expert's Perceptions

This section discussed about the recommendations that have been identified during the interview according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' of selected urban wetlands that extracted from institutional stakeholder expert's perceptions as that followed the fifth objective and the fifth research question that have been developed in this research.

5.1.4.1 Attribute - 1: 'Contribution for biodiversity conservation and enhancement'

Institutional stakeholder expert's think that, waste materials and waste water from different sources as households, industries, clinical, commercial setup etc. should be stopped immediately; wetland water should be clean and improved first; need to conserve these urban water bodies as soon as possible for biodiversity conservation, ecosystem development and co-existence; local people should know about biodiversity conservation; pollution awareness should be ensured among urban dwellers to cope with different urban wetland connecting problems; improvement of sewerage connection should be ensured by related institutions; re-excavation of these urban water bodies is urgently needed; encroachment should be prevent; strict daily monitoring, maintenance needs to follow from relevant authorities on pollution issues; if we can work towards conservation by proper planning, decision and implementation in coming near future, this situation can be improved; for future improvement, firstly urbanism should be done on this sector; engage youth peoples towards conservation are important; urban population is so detached from nature now, connect with nature is important; if proper steps will be taken, still these water bodies can conserve, example as Dhanmondi and Hatirjheel urban wetlands in Dhaka city; now everybody understanding and taking steps on these water issues, example as taking steps on River encroachment now, it is a good decision at all; as these are the responsibility of Dhaka City Corporation and other organizations, as well as urban dwellers have responsibility also as a citizen for these issues as well; Dhaka is expanding towards Ashulia and Birulia water bodies areas, if we still cannot manage properly, what we have still now, that will also destroy in future for industrial pollution etc.

5.1.4.2 Attribute - 2: 'Resilience of urban water bodies to face the challenge of climate change impacts'

5.1.4.2.1 Cooling Effect During Summer on Heat Stress of Selected Urban Wetlands

Institutional stakeholder expert's think that, climate change is a burning issue now days for the world now. So, it is very much required to conserve these urban water bodies in any cities of the world, in Dhaka this is urgently needed to retreat these water bodies to support climate change impacts issues; to absorb the heat, it is urgently need urban wetland conservation; as these water bodies have capacity to store carbon naturally, so it is top most concern to conserve and restore anyhow of these water bodies; if there is enough trees bank of the water body it could be good for cooling surrounding environment; presence of trees is equally important as wetlands did for the city, it can reduce urban temperature, air pollution, can work as transpiration system, so this issue should be considered for climate change impacts; source pollution points should be stopped as vehicles smoke, industrial pollution, solid waste etc.; urban wetlands, urban forest, urban biodiversity etc. these are new sectors actually. A few works have been done on these sectors still now. We understand as forest means Sundarban or Vawal etc. and others. But still, we cannot understand that forest can create in urban areas also, example as Germany city forest is very beautiful and urban forest of Singapore etc.; therefore, to save the peoples of Dhaka city, we have to think towards the conservation of these water bodies in a sustainable way and our future plan should be in that way. We cannot live only on paved concrete area, we cannot live healthier, so we need these wetlands to live in the city. To create a livable city concept, these wetlands are the basic needs, otherwise, a city will not be a livable city etc.

5.1.4.2.2 Storage Capacity During Heavy Rainfall on Flood Stress of Selected Urban Wetlands

Institutional stakeholder expert's think that, flood is very much common problem for the city these days, by proper conservation, management and re-development of these water bodies by DSCC and other organizations are needed to sustain these water bodies in future (as example, flood situation in Dhanmondi Lake areas now resolved already); these wetlands management are also important for natural drainage systems of the city. If internal connection properly exists, drainage capacity also can increase. So, for proper conservation and management of the urban water bodies, it is needed to restore connectivity among the water bodies etc.

5.1.4.3 Attribute - 3: 'Contribution for community livelihood'

Institutional stakeholder expert's think that, for the future development, waste management should be one of the first priorities; need pollution management for livelihood improvement; to ensure whether the local poor people can get this livelihood opportunity or not that is important; to develop community livelihood more, water bodies in urban setting its needed community involvement; different awareness and movement work for local people towards sustainable conservation, restoration and management should be ensured; these urban wetlands are very much important for us and big assets for the city as well. There is opportunity on community livelihood exists in Ashulia, Birulia urban wetlands still now, if others wetlands can work properly, there will be hope still now on those urban wetland's future livelihood development; if environment will be clean and safe, livelihood development will also increase more in urban wetlands, as an example Ramna Lake and Park area have been improving, now tourism-based livelihood should be ensured in this wetland in future; once there were many lakes in the Dhaka city, those lakes located in Dhaka city map were connected to each other. Recently Government have taken plan to re-connect these lakes again. Therefore, if these lakes will connect internally, it will be useful for communication as by introduce water transports, water taxi etc. for livelihood opportunity and at the same time this will be an excellent for people that they also can feel these wetlands etc.

5.1.4.4 Attribute - 4: 'Adequacy of the policy regime'

Institutional stakeholder expert's think that, to improve the present situation, everybody has to aware of relevant Government policies as maximum population in the capital does not aware about what those policies are; for future development strict enforcement of these rules, policies, acts are urgently needed by relevant authorities; if there was proper strict implementation of Government policies, laws exist on these urban wetlands, these polluted situations cannot take place in recent times. So, everybody needs to follow those laws and all challenges may be able to overcome; need to be strict maintenance of these policies; policies should be implement in detailed way and these should be action oriented; to follow Detailed Area Plan (DAP), Urban Area Plan, Structural Plan and other Plan etc. strictly; to form a strong strict committee jointly Government and other relevant institutions and organizations to resolve strict implementation improvement on this issue and should be applicable with proper actions in every sector; these policy sectors should have proper resource facilities, manpower facilities and should have adequate budget to policy implementation as well.

5.6.5 Attribute - 5: 'Local acceptance and credibility of the role of relevant institutions'

Institutional stakeholder expert's think that, every organization that is related to urban wetland management issues, should play their specific roles on planning, monitoring, implementing at every stage of development; every organization must be won by themselves and should do their respective individual works in more effective ways; planning should be strong where 'water will be a main component'; in the planning phase, hydro-morphological study should be strong enough on selected water bodies by related organizations; Detailed Area Plan (DAP) should be strong; for future development, a sustainable development planning should be developed thinking in mind on overall Green-Blue network; need proper planning for next 20 years and think about this issue immediately; awareness about urban wetland valuation among city dwellers should be exist; solid waste and waste water are the main obstruction for urban water bodies' conservation, so it should need careful handle from respected authorities; to get a smooth sustainable water body, pollution, encroachment, connectivity between urban water courses, livelihood development for urban dwellers etc. should be ensured by the Government and other organizations; proper demarcation line and land acquisition issues in urban water bodies should be ensured; there should be exists more strong political commitments on this present urban wetland issues accordingly; community empowerment can be an important tool for urban and sub-urban water bodies management, so it can be introduced in each urban and sub-urban water bodies restoration by relevant authorities in and around the Dhaka city; all strategies connecting these urban water bodies should be properly and strictly maintained; for the future development, all authorities must be strict towards conservation and management of these water bodies; adequate drainage facilities should be ensured by relevant authorities in the city; a sustainable management approach should be developed where local level and community level participation should be ensured; an integrated water resource-based management should be developed; to re-store and re-treat urban wetlands through adequate pollution measures, policy measures etc. should be ensured; to attract higher policy level peoples by giving proper direction is important; for the future development work, Fisheries Department and DoE can jointly perform in implementation of 'ecosystem-based management on integrated way' as well; there are several plans of further development on Dhanmondi Lake urban water body. Different steps of management work still approved by the Government to construct near future; DWASA should do more in future for improvement on these issues; for PWD, in future, some of maintenance options need to be ensured by the authorities. Should increase maintenance staffs, to improve safety and security more etc. Should increase drinking water sources etc.; recent example as ‘Nodi Rokha Trust’ doing different movement works and prevention of encroachment works around the Rivers of Dhaka city. This is a good example for everyone towards conservation of urban water bodies; Ashulia water body has been getting in bad situation and needs to conserve and save urgently; Government should take steps directly on their hands as soon as possible for our local poor people; Empower UP and other local institutions for conservation of this water body; should take steps on implement laws, regulations to control pollution and encroachment; to ensure treatment of polluted water in every industry and factory; should improve water transport for less oil pollution; should provide accurate dredging; to introduce ‘net systems’ during rainy season for fishing; to culture enough fishes for the economic development for local fishermen; should increase agricultural development enough for financial profit to local people; should plant enough trees and plants besides the water body; to introduce new cheap systems for modern brick kiln factories with less pollution as maximum economic profit we have been gaining by this; for future improvement, higher authorities should be very strong and strict to stop the pollution; to improve and introduce more agricultural practices; to improve the quality of water for fish and other aquatic species; to improve modern brick manufacturing steps so as to clean the environment; to stop source pollution; to stop industries, factories waste water disposal connection properly; to participate local level organization involvement for conserve and maintenance; higher authorities should monitor timely about the quality of water etc. are urgent to implement; in Birulia, higher authorities should be very strong and strict to stop the pollution; to improve and introduce more agricultural practices; to improve the quality of water for fish and other aquatic species; to improve and introduce modern brick manufacturing steps with low cost so as to clean the environment; to stop source pollution; to stop industries, factories waste water disposal connection properly; pollution connecting awareness rising campaign for local people and industries; to participate local level organization involvement for conserve and maintenance; there is huge lack of monitoring this area by respected higher authorities, but in future higher authorities should monitor timely about the quality of water and should take strict necessary steps to improve etc. are urgent to implement; recently much development has been existing on environment sector, environment and ecosystem both have been getting emphasis recently. Now Bangladesh have come to the middle-income city, may be go to the developed country in future, therefore, still we have time to take proper steps taken by all on this water issues etc.

(III) Author Personal Field Observation

This section discussed the field observation that conducted by the author that covering the general information of study area and results of field observation according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' in seven study areas.

5.1.3 Study Area

This section discussed about the general information of the study area as follows:

5.1.3.1 Study area - 1: Dhanmondi Lake

Dhanmondi Lake is a permanent urban wetland located in the Dhanmondi planned residential area within Dhaka city which has been used extensively as a recreational open space with pleasing environment from long time (Figure – 5.1).

Figure – 5.1: A recreational open space in Dhanmondi Lake in dry season (Source: Author personal field observation)

Within this urban wetland, bank side's area is extensively used by different population for different physical and recreational use in the morning and evening. To increase user's activity, different spots as jogging track, playground for children, exercise spaces etc. have been observed (Figure – 5.2).

Figure – 5.2: Different spots as jogging track, playground for children, exercise spaces located in Dhanmondi Lake in dry season (Source: Author personal field observation)

Walk ways, foot Bridges, public toilets, sitting arrangement for visitors etc. have been observed as well (Figure – 5.3).



Figure – 5.3: Walk ways and pedestrian Bridges located surrounding the Dhanmondi Lake in dry season (Source: Author personal field observation)

This urban wetland has become a widespread entertainment spot with cultural centers of open-air Amphitheater as Rabindra-Sarobar, located along its bank side is the spot for concerts, theater presentations, spot for media shooting and variety of cultural programs, festivals and holiday celebrations etc. Peoples gathered here during various festivals such as Pohela Baishakh, Independence Day, Eid etc. for recreation (Figure – 5.4).


Figure – 5.4: Open-air Amphitheater as Rabindra-Sarobar, located along lake bank side is the spot for variety of cultural programs, festivals and holiday celebrations within Dhanmondi Lake in dry season (Source: Author personal field observation)

5.1.3.2 Study area - 2: Gulshan-Baridhara Lake

Gulshan-Baridhara Lake has been contributing an important role within Gulshan and Baridhara parts of Dhaka metropolis. Gulshan area that is one of the diplomatic zones in Dhaka city, covering a commercial and residential place. Different high-rise multistoried commercial development as offices, commercial corporate complexes, restaurants, embassies, shops, markets etc. and residential settlements already exists in this place.

Figure – 5.5: Current situation of the Gulshan-Baridhara Lake in dry season (Source: Author personal field observation)

Gulshan-Baridhara Lake divided by two classes of residents. In west side of the lake, 'Gulshan' there has been living higher class and higher middle-class families of residents and in east side of 'Badda' has been living middle- and lower-income residents as well (Figure – 5.5).

5.1.3.3 Study area - 3: Hatirjheel Lake

In Dhaka city, Hatirjheel Lake has become the largest fresh water body located just in the midst of major city areas which acts as a natural water retention basin and aesthetic greenery recreational breathing space (Figure – 5.6).

Figure – 5.6: Current situation of the Hatirjheel Lake in dry season (Source: Author personal field observation)

From the field observation in Hatirjheel Lake, this urban wetland associated with express road network systems, viaducts, bridges, walk ways, recreational gathering open spaces, water front landing steps (ghats), viewing deck, water bus terminal spaces of different roots, playing grounds for children, music fountain and pleasantly landscaped with different trees and vegetation etc. Novo Theatre as Amphitheatre is the new waterfront innovation that added more enjoyment facilities in the area as well (Figure – 5.7).

Figure – 5.7: Walk way, ghat, water taxi/bus and Novo Theatre in the Hatirjheel Lake in dry season (Source: Author personal field observation)

Some years back, after implementation of different development projects in this area, different peoples from different places of the city come to visit this place. Different activities as playing of children's and active recreation are exist in this urban wetland (Figure – 5.8).

Figure – 5.8: Different user activities in the Hatirjheel Lake in dry season (Source: Field observation by the author during survey)

5.1.3.4 Study area - 4: Ramna Lake

In Dhaka city, Ramna Lake has become the closed fresh urban wetland located just in the middle of the major city areas which acts as a natural water retention basin from long time. This urban wetland has been acting as a vast open space covered with large water area having cool breeze environment which attracts the visitors normally. People of different ages come to visit this beautiful lake all the time for it's aesthetic greenery recreational breathing spaces (Figure – 5.9).

Figure – 5.9: Current situation of Ramna Lake in dry season (Source: Author personal field observation)

5.1.3.5 Study area - 5: Diabari Bottola Lake

Diabari Bottola Lake located in the Uttara area within Dhaka city which has been used extensively as a recreational open space with pleasing environment by different population in the morning to evening (Figure – 5.10).

Figure – 5.10: Current situation of Diabari Bottola Lake in dry season (Source: Author personal field observation)

5.1.3.6 Study area - 6: Ashulia urban wetland

Ashulia urban wetland is located at the north-western part of Dhaka Metropolis in Ashulia Union under Savar Thana. This urban wetland is sited within the west and south active flood flow plains of surrounding rivers (mainly Turag River) within Dhaka city. This area remains under water for about five to six months of the year from May to September and rest of the time this area remains dry. In the rainy season, this urban wetland is a temporary fresh water wetland that plays a vital role as catchment areas in enabling the drainage of water from Dhaka city. The lowlands of Ashulia urban wetland serve as the withholding body for the surplus water of the Turag and Balu Rivers during rainy season (Figure – 5.11).

Figure – 5.11: Ashulia urban wetland during dry and monsoon season (Source: Author personal field observation)

5.1.3.7 Study area - 7: Birulia urban wetland

Birulia urban wetland is located near to Birulia small village that is under Birulia Union and Ashulia Thana of Savar Upazila near to Dhaka Metropolis. This urban wetland located on the banks of the Turag River distributaries. Once this is the place for Zamindars for their own business. There are lot of architectural historical buildings of Zamindars still exist in this area which have been used by the local people of the area now. This urban wetland is connected by a Bridge and a road from Mirpur-Ashulia Road.

Figure – 5.12: Birulia urban wetland in during dry and monsoon season (Source: Author personal field observation)

From the field survey in Birulia wetland, two types of scenery have been observed here, as both dry and rainy season pictures. It is not only a heritage site but also a natural setting of area which turns it into a picturesque island that surrounded by vast volume of water during the monsoon season for about five to six months in a year and rest of the time of the year this place almost remains dry in the winter which turned into vast green paddy and other vegetables fields (Figure – 5.12).

5.1.3 Current Scenario and Existing Role of Selected Urban Wetlands According to the Urban Wetland Sustainability Framework (UWSF) Model – 1

This section prefers the current scenario and existing role of selected urban wetlands according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' from author personal field observation and analyzed with five-point Likert scale that followed the first objective and the first research question that have been developed in this research.

5.1.3.1 Attribute - 1: 'Contribution for biodiversity conservation and enhancement'

According to this Attribute – 1, aquatic plant diversity, fish species, other aquatic animal species, terrestrial tree species, terrestrial wildlife species, terrestrial bird species using English and local name and the scale of contribution according to the author personal field observation on seven study areas have been discussed as follows:

5.1.3.1.1 Study area - 1: Dhanmondi Lake

(a) Aquatic Plant Diversity

According to author observation, total three (3) species of aquatic plants as Water spinach (Kolmi), Water lily (Shapla - few), Water hyacinths (Kochuripana) etc. have been observed (Figure – 5.13).

Figure – 5.13: Few aquatic floras as water lily and different species of aquatic water plants have been observed in Dhanmondi Lake in dry season (Source: Author personal field observation)

(b) Fish Species

Total two (2) species of fishes as Tilapia (Tilapia), small fishes etc. have been observed.

(c) Other Aquatic Animal Species

Aquatic wildlife species have not seen in this water body.

(d) Terrestrial Tree Species

Total sixteen (16) species of terrestrial trees as varieties of shaded lot of trees as Palm tree (Palm), Banyan tree (Bot), Elephant apple (Chalta), Guava (Peara), Royal Poinciana (Krishnochura), Mahogany (Mehogoni), Raintree (Raintree), Mango (Aam), Bitter oleander (Kurchi), Barringtonia acutangula (Hizol), Berry (Jam), Azadirachta indica (Neem), Golden Shower tree (Shonalu), Jackfruit (Kathal), Plum (Boroi), Water apple (Jamrul) etc. are available on the both bank sides of this lake have been observed (Figure – 5.14).

Figure – 5.14: Both banks of Dhanmondi Lake is covered by lush green vegetations and big shaded trees in dry season (Source: Author personal field observation)

(e) Terrestrial Wildlife Species

Total six (6) species of terrestrial wildlife as Swan (Rajhash), Duck (Hash), Squirrel (Kathbirali), Dog (Kukur), Cat (Biral), Butterfly (Projapoti) etc. have been observed (Figure – 5.15).

Figure – 5.15: Some species of terrestrial wildlife have been observed in Dhanmondi Lake in dry season (Source: Author personal field observation)

(f) Terrestrial Bird Species

Total ten (10) species of terrestrial birds as Purple sunbird, Oriental magpie-robin (Doel), Pigeon (Kobutor), Alexandrine parakeet (Tia), Cuckoo (Kokil), Passerine birds (Bulbuli), Sparrow (Choroi), Gracula (Shalik), Black kite (Cheel), Crow (Kak) etc. have seen in this water body have been observed (Figure – 5.16).

Figure – 5.16: Different species of birds with high significance of conservation have been observed in Dhanmondi Lake in dry season (Source: Author personal field observation)

(g) Author Personal Field Observation According to the Scale of Contribution on Attribute - 1

According to field observation in Study area - 1: Dhanmondi Lake, urban wetland has been performing 'less effective contribution' for biodiversity conservation and enhancement in recent time as much pollution by the public (users and visitors) due to unawareness on water pollution, declining the water quality in this lake; back sides of the lake their observed primary collection point of solid waste by Dhaka City Corporation vehicles. That place is full of bad odor all the time for waste disposal and collection. During rain, storm water can accumulate these waste liquids from this place to the water body by surface runoff; in rainy season, wastes from lake surrounding areas seepage in the lake that observed almost common here. This can easily destroy the biodiversity and ecosystem of aquatic environment in this lake; some open defecation places also observed some areas of the lake that has been causing fecal contamination of the lake water that can transmit diseases; brown-greenish turbid water in winter season showed organic matter pollution, comparatively high level of sediment and nutrient load in water that may reduce the water quality and depth of the lake; for excess pollution these days, self-cleansing capacity has been declining in this urban water body; has been decreasing Dissolved Oxygen (DO) level, enhance Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Total Dissolved Solid (TDS) etc.; by releasing phosphorus as phosphate (PO4) from solid, liquid wastes etc., it may lower the water quality in this freshwater ecosystem; have been degrading aquatic food chain, quantity, quality of aquatic all species and overall habitat; polluted water also interrupting water dependent birds, animals etc.; fruit bearing trees for birds, insects etc. observed less; aquatic water filtration flora (as water lily, lotus etc.) observed very less; different trees, plants species of terrestrial biodiversity both bank sides area added a good environmental benefit for water dependent terrestrial species with aquatic species as well; lots of birds with high conservation significance have seen surrounding the water body; water level have been observed higher in monsoon than winter etc.

5.1.3.1.2 Study area - 2: Gulshan-Baridhara Lake

(a) Aquatic Plant Diversity

According to author observation, total one (1) species of aquatic plants as Water hyacinths (Kochuripana) have been observed.

(b) Fish Species

Total three (3) species of fishes as River catfish (Pangash - dead floated), Catfish (Magur), Tilapia (Tilapia) etc. have been observed (Figure – 5.17).

Figure – 5.17: Dead fish floating River catfish (Pangash) on the Gulshan-Baridhara Lake in dry season (Source: Author personal field observation)

(c) Other Aquatic Animal Species

Total two (2) species of aquatic wildlife as Snail (Shamuk), Frog (Bang) etc. have been observed.

(d) Terrestrial Tree Species

Total nine (9) species of terrestrial trees as Giant crepe-myrtle (Jarul), Banana (Kola), Azadirachta indica (Neem), Royal Poinciana (Krishnochura), Jackfruit (Kathal), Papaya (Pepey), Mango (Aam), Guava (Peara), Lemon (Lebu) etc. are available on the both bank sides of this lake have been observed (Figure – 5.18).

Figure – 5.18: Different varieties of terrestrial shaded trees on the edge of the lake in Gulshan side area and few amount of greenery and shaded trees in Badda side area in dry season (planted some years back) (Source: Author personal field observation)

(e) Terrestrial Wildlife Species

Total three (3) species of terrestrial wildlife as Squirrel (Kathbirali), Cat (Biral), Dog (Kukur) etc. have been observed.

(f) Terrestrial Bird Species

Total four (4) species of terrestrial birds as Crow (Kak), Gracula (Shalik), Sparrow (Choroi), Pigeon (Kobutor) etc. have seen in this water body.

(g) Author Personal Field Observation According to the Scale of Contribution on Attribute - 1

In Study area - 2: Gulshan-Baridhara Lake, water body has been performing 'not effective at all' as the water quality of this urban water body observed much polluted with enough turbid brown-greenish in color with bad odor mainly in winter season; wastes from Gulshan bank side, Badda bank side areas, nearby restaurants, hospitals, industries, construction and other wastes have been discharging directly and indirectly in this water body by different outfalls; water level have been observed higher in monsoon than winter; pollution can create excess toxic sludge in the lake bed and can reduce the lake bed; this lake is looking like a polluted ditch now in some places; upper level of this lake water observed acidic some places; mosquito breeding observed some areas; these pollution has been destroying the biodiversity and ecosystem of aquatic environment in this lake; has been decreasing Dissolved Oxygen (DO) level, enhance Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Total Dissolved Solid (TDS) etc.; by releasing phosphorus as phosphate (PO4) from solid, liquid wastes etc., it may lower the water quality in this freshwater ecosystem; have been degrading aquatic food chain, quantity, quality of aquatic all species and overall habitat; some fishes (mainly Pangash) observed dead floated on the water in winter season; some open defecation places also observed during survey at the near to the bank of the lake that causing fecal contamination of the lake water. That degrading microbial quality of lake water and can enhance different water related disease transmission; much open water outfall observed surrounding this lake for storm water drainage discharge that has been declining the lake water directly; over polluted water also interrupted water dependent birds, animals etc.; as pollution level observed very high, it is so difficult to filter high polluted water by this water body through its self-cleansing system scientifically; may cannot working properly on air quality improvement function; surrounding industrial waste and waste water can enhance heavy metal concentration in the water body; absence of big shaded trees on the Badda bank observed; wildlife species found less in quantity; aquatic water filtration flora as water lily, lotus etc. did not observe in this lake; flowery plants, trees observed less as butterflies, bees etc. are depending on them etc.

5.1.3.1.3 Study area - 3: Hatirjheel Lake

(a) Aquatic Plant Diversity

According to author observation, total two (2) species of aquatic plants as Water hyacinths (Kochuripana) and Water spinach (Kolmi) etc. have been observed.

(b) Fish Species

One (1) species of fishes as Catfish (Magur) have been observed.

(c) Other Aquatic Animal Species

Aquatic wildlife species have not seen in this water body.

(d) Terrestrial Tree Species

Total eleven (11) species of terrestrial trees as Palm tree (Palm), Giant crepe-myrtle (Jarul), Raintree (Raintree), Gorjan tree (Gorjan), Barringtonia acutangula (Hizol), Royal Poinciana (Krishnochura), Mango (Aam), Jackfruit (Kathal), Banana (Kola), Berry (Jam), Water apple (Jamrul) etc. have been observed (Figure – 5.19).

Figure – 5.19: Existing status of large areas covering with trees and vegetation on both banks of the Hatirjheel Lake in dry season (Source: Author personal field observation)

(e) Terrestrial Wildlife Species

Total two (2) species of terrestrial wildlife as Squirrel (Kathbirali) and Dog (Kukur) etc. have been observed.

(f) Terrestrial Bird Species

Total five (5) species of terrestrial birds as Gracula (Shalik), Egret birds (bok), Oriental magpie-robin (Doel), Sparrow (Choroi), Crow (Kak) etc. have seen in this water body.

(g) Author Personal Field Observation According to the Scale of Contribution on Attribute - 1

In Study area - 3: Hatirjheel Lake, water body has been performing ‘not effective at all’ as the water quality of this urban water body observed polluted with enough turbid water with bad odor mainly in winter season; as water quality is a major concern now, so without proper mitigation and retreatment it will be very difficult for the water body to play the ecological role in coming future; drainage problem exist still now in this water body; water level have been observed higher in monsoon than winter; contaminated sewerage water can develop microbial contamination (coliform bacterial transmission) in this lake; as water quality has been degrading, it will naturally affect the aquatic species and terrestrial water dependent animals; for recent bad water quality of the lake through high loaded pollution may not be able to perform water filtration system by this water body effectively; may cannot working properly on air quality improvement function; has been decreasing Dissolved Oxygen (DO) level, enhance Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Total Dissolved Solid (TDS) etc.; by releasing phosphorus as phosphate (PO4) from solid, liquid wastes etc., it may lower the water quality in this freshwater ecosystem; surrounding industrial waste and waste water can enhance heavy metal concentration in the water body; have been degrading aquatic food chain, quantity, quality of aquatic all species and overall habitat; aquatic water filtration flora as water lily, lotus etc. did not observe in this lake; less habitat of terrestrial fauna (as birds, wildlife species etc.) observed in this water body etc.

5.1.3.1.4 Study area - 4: Ramna Lake

(a) Aquatic Plant Diversity

According to author observation, total three (3) species of aquatic plants as Water spinach (Kolmi), Water hyacinths (Kochuripana), Water lettuce (Topapana) etc. have been observed (Figure – 5.20).

Figure – 5.20: Aquatic plants surrounding the Ramna Lake in dry season (Source: Author personal field observation)

(b) Fish Species

Total one (1) species of fishes as Tilapia (Tilapia) have been observed.

(c) Other Aquatic Animal Species

Total one (1) species of aquatic wildlife as Snail (Shamuk) have been observed.

(d) Terrestrial Tree Species

This urban wetland is situated within the Ramna Park area. Different species of huge old shaded trees, plants, shrubs and grasses are observed surrounding the Ramna Lake that has been contributing high significance of terrestrial strong ecosystem (Figure – 5.32). Total eighteen (18) species of terrestrial trees as bush type huge different local plant species, huge flowery, medicinal, wood-based tree species as Bokul tree (Bokul), Raintree (Raintree), Royal Poinciana (Krishnochura), Banyan tree (Bot), Almond tree (Kath Badam), Mango (Aam), Jackfruit (Kathal), Berry (Jam), Water apple (Jamrul), Giant crepe-myrtle (Jarul), Plum (Boroi), Banana (Kola), Bullet Wood (Dumur), Gooseberry (Amloki), Coconat (Narikel), Eucalyptus tree (Eucalyptus), Acacia auriculiformis (Akasmoni) etc. are available on the both bank sides of this lake have been observed (Figure – 5.21).

Figure – 5.21: High significance of terrestrial strong ecosystem and user activities in Ramna Lake in dry season (Source: Author personal field observation)

(e) Terrestrial Wildlife Species

Total seven (7) species of terrestrial wildlife as Cat (Biral), Squirrel (Kathbirali), Swan (Rajhash), Duck (Hash), Dog (Kukur), Butterfly (Projapoti), Grasshopper (Foring) etc. have been observed (Figure – 5.22).

Figure – 5.22: Aquatic plants and terrestrial wildlife surrounding the Ramna Lake in dry season (Source: Author personal field observation)

(f) Terrestrial Bird Species

Total three (3) species of terrestrial birds as Oriental magpie-robin (Doel), Gracula (Shalik), Crow (Kak) etc. have seen in this water body.

(g) Author Personal Field Observation According to the Scale of Contribution on Attribute - 1

In Study area - 4: Ramna Lake, water body has been performing 'moderately effective contribution' as this water body observed comparatively less polluted; huge abundant of water that provides a good breeding ground and good shelter for fishes; water level have been observed higher in monsoon than winter; no outside outfalls or pipes are observed for pollution from outside the lake area; as pollution level observed comparatively low and well maintained by respected authorities, so the self-cleansing system may be can work to filter water by this water body effectively; this water body observed playing a vital role for biodiversity and ecosystem conservation; during rainy season lake water observed some pollution through surrounding organic waste and waste water runoff but that is negligible; the growth of aquatic plant species as water lily, lotus, etc. is apparently absent in this urban water body which can hamper the pollution filtration system (as these plants have pollution filtration capacity as well) in the water and scenic aesthetic views; has been contributing terrestrial based strong ecosystems from the ancient time in the city; there is huge abundance of trees, vegetation of terrestrial biodiversity observed on the both bank sides of the water body which can enhance the good environmental balance; as this water body surrounded by a park, it added an extra ordinary environmental impact to the city dwellers for recreation as well; also noticed that, different alien invasive trees as Eucalyptus, Raintree, Akashmoni etc. are invaded the lake surroundings that are not environment friendly at all as these alien species soak high amount of water from ground water aquifer, native species cannot live near to these aliens and overall, not suitable for our country in Bangladesh. Birds also not feel comfortable to sit on these aliens at all; observed a comparatively less habitat for terrestrial fauna (wildlife species); some birds observed as many trees are present in surrounding areas etc.

5.1.3.1.5 Study area - 5: Diabari Bottola Lake

(a) Aquatic Plant Diversity

According to author observation, total four (3) species of aquatic plants as Water lettuce (Topapana), Water spinach (Kolmi), Water hyacinths (Kochuripana) etc. have been observed. (Figure – 5.23).

Figure – 5.23: Species of aquatic water plants has been observed in Diabari Bottola Lake in dry season (Source: Author personal field observation)

(b) Fish Species

Total three (3) species of fishes as Climbing perch (Koi), Stinging catfish (Shing), Catfish (Magur) etc. have been observed.

(c) Other Aquatic Animal Species

Total two (2) species of aquatic wildlife as Snail (Shamuk) and Oyster (Jhinuk) etc. have been observed.

(d) Terrestrial Tree Species

Total five (5) species of terrestrial trees (less tree species have found) as Banana (Kola), Royal Poinciana (Krishnochura), Papaya (Pepey), Plum (Boroi), Willow and hazel (Kashful) etc. have been observed.

(e) Terrestrial Wildlife Species

Total three (3) species of terrestrial wildlife as Cow (Goru), Horse (Ghora), Butterfly (Projapoti) etc. have been observed.

(f) Terrestrial Bird Species

Total four (4) species of terrestrial birds as Oriental magpie-robin (Doel), Sparrow (Choroi), Gracula (Shalik), Crow (Kak) etc. have seen in this water body.

(g) Author Personal Field Observation According to the Scale of Contribution on Attribute - 1

In Study area - 5: Diabari Bottola Lake, water body has been performing 'moderately effective contribution' as from field observation physically the lake water quality found comparatively less polluted in recent times to play an important role on conservation of aquatic biodiversity and ecosystems; use of organic fertilizers for growing crops to perform agricultural activities by local farmers is another cause for less water pollution in this area; there are two storm water pipe connections have given directly within this lake, where solid waste and wastes have been entered to this water body and polluted this lake, but their intensity is comparatively less observed; dumping of some wastes on the bank sides of the water body from visitors has been degrading the lake environment for unawareness of pollution; as this area found less developed and urbanized than other areas of Dhaka city, pollution found is still less. Therefore, the water quality of this water body observed less polluted to filter surrounding waste and waste water to perform on water bodies 'self-cleansing system' as well.; as this place has been newly re-developed, there are comparatively fewer terrestrial species observed surrounding this water body still now; if solid waste will not maintain in future strictly, water quality of this beautiful water body can degrade as other selected urban water bodies that will directly hamper aquatic biodiversity (flora and fauna) and finally valuable whole ecosystem at all; water level have been observed higher in monsoon than winter etc.

5.1.3.1.6 Study area - 6: Ashulia urban wetland

(a) Aquatic Plant Diversity

According to author observation, total four (4) species of aquatic plants as Water lettuce (Topapana), Water hyacinths (Kochuripana), Water spinach (Kolmi) and grass type small plants on the bank have been observed.

(b) Fish Species

Total five (5) species of fishes as Catfish (Magur), Stinging catfish (Shing), Climbing perch (Koi), Striped snake head (Shole), Mola fish (Mola - dead floated) etc. have been observed.

(c) Other Aquatic Animal Species

Total three (3) species of aquatic wildlife as Snail (Shamuk), Oyster (Jhinuk) and Frog (Bang) etc. have been observed.

(d) Terrestrial Tree Species

Absence of trees surrounding this water body have been observed.

(e) Terrestrial Wildlife Species

Total three (3) species of terrestrial wildlife as Duck (Hash), Hen (Murgi) and Butterfly (Projapoti) etc. have been observed.

(f) Terrestrial Bird Species

Total two (2) species of terrestrial birds as Gracula (Shalik) and White Egret birds (Shada bok) etc. have seen in this water body.

(g) Author Personal Field Observation According to the Scale of Contribution on Attribute - 1

In Study area - 6: Ashulia urban wetland, water body has been performing 'not effective at all' as the water quality of this sub-urban water body observed polluted deep brown or almost black with bad odor in winter season; water level have been observed highest in monsoon, the water almost dried in winter season; dumping of solid waste from domestic and huge industrial part observed on the bank of the water body on the embankments (road embankment of Ashulia-Mirpur Road is divided by the water body of two sides here that can easily destroy the aquatic biodiversity and ecosystem of the environment in this wetland; pollution can create excess toxic sludge in the wetland; the water quality of Ashulia water body found muddy (turbid) and polluted enough to filter waste and waste water in fact in both seasons. So, it is difficult to this water body to perform on 'self-cleansing system' as well; may cannot working properly on air quality improvement function; physically the water quality is not good to play ecological role effectively at all; Ashulia water body has been extremely polluted in recent times due to recent urban development; this water body is become a dumping ground of all kinds of solid, construction, liquid and chemical wastes of both banks (embankment) sides of inhabitants and industries that receives millions tones of sewages, domestic wastes, industrial and agricultural effluents every day; even it was observed that solid wastes dumping on the banks of water bodies and also as this water body merges with the adjacent polluted Turag River, it is naturally deteriorated the water; there are less terrestrial and aquatic species have observed surrounding this water body; the industrialization, unplanned urbanization has been affecting all fishes and most of the aquatic animals to death, disruption of food chains and destruction of ecosystems of this sub-urban wetland area; some fishes observed dead floated on the water in winter season; this water pollution has been affecting the surrounding agricultural land and fertile land environment as well; coal dumping and store on the bank of water body observed another problem of water pollution that threatening floral and faunal species; has been decreasing Dissolved Oxygen (DO) level, enhance Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Total Dissolved Solid (TDS) etc.; besides, chemical fertilizer (to grow crops) and external medicine (to control pests) are other sources of water pollution in this area; by releasing phosphorus as phosphate (PO4) from solid, liquid wastes, chemical fertilizers, pesticides etc., it may lower the water quality in this freshwater ecosystem; surrounding industrial waste and waste water can enhance heavy metal concentration in the water body; over polluted water also interrupted water dependent birds, animals etc.

5.1.3.1.7 Study area - 7: Birulia urban wetland

(a) Aquatic Plant Diversity

According to author observation, total five (5) species of grass type small plants on the bank, (Khudipana), Water spinach (Kolmi), Water hyacinths (Kochuripana) and Water lettuce (Topapana) etc. have been observed.

(b) Fish Species

Total four (4) species of fishes as Puntius fish (Puti - dead floated), Small shrimp (Chingri), Khoilsha fish (Khoilsha) and small fishes have been observed.

(c) Other Aquatic Animal Species

Total four (4) species of aquatic wildlife as Local Dolphin (Shushokh), Small Turtle (Choto Kochop), lots of Snail (Shamuk) and Oyster (Jhinuk) etc. have been observed.

(d) Terrestrial Tree Species

Total nine (9) species of huge local fruit trees as Lichi (Lichu), Mango (Aam), Berry (Jam), Water apple (Jamrul), Jackfruit (Kathal), Coconut (Narikel), Betel nut palm (Supari), Banyan tree (Bot) and Guava (Peara) etc. have been observed.

(e) Terrestrial Wildlife Species

Total four (4) species of terrestrial wildlife as Duck (Hash), Hen (Murgi), Cow (Goru), Goat (Chagole) etc. have been observed (Figure – 5.24).

Figure – 5.24: Wildlife biodiversity in Birulia urban wetland in dry season (Source: Author personal field observation)

(f) Terrestrial Bird Species

Total two (2) species of terrestrial birds as Crow (Kak) and Sparrow (Choroi) etc. have seen in this water body.

(g) Author Personal Field Observation According to the Scale of Contribution on Attribute - 1

In Study area - 7: Birulia urban wetland, water body has been performing 'not effective at all' as the water quality of this urban water body observed polluted deep brown with foul odor mainly in dry season; water level have been observed highest in monsoon, the water almost dried in winter season; it is so difficult for this water body to perform any 'self-cleansing systems' in recent times as this water body has been polluted through different effluent; may cannot working properly on air quality improvement function; physically the water quality is not good to play effective ecological role at all; different wastes dumping and store on the bank of water body is a problem of water pollution that can threaten floral and faunal species; oil contamination by water transport in Turag distributaries can ultimately affecting the aquatic species in this water body; due to recent urbanization, this water body has been polluted by various wastes such as agricultural, industrial, construction, household wastes etc. that directly has been stressed on this freshwater ecosystems and biodiversity; pollution can create excess toxic sludge in the wetland; have been degrading aquatic food chain, quantity, quality of aquatic all species and overall habitat; these pollution also affects the surrounding agricultural land of this water course area; other way, as this water body is a floodplain of Turag River, polluted river water has been deteriorated this Birulia sub-urban wetland; has been decreasing Dissolved Oxygen (DO) level, enhance Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Total Dissolved Solid (TDS) etc.; besides, chemical fertilizer (to grow crops) and external medicine (to control pests) are other sources of water pollution in this area; by releasing phosphorus as phosphate (PO4) from solid, liquid wastes, chemical fertilizers, pesticides etc., it may lower the water quality in this freshwater ecosystem; surrounding industrial waste and waste water can enhance heavy metal concentration in the water body; over polluted water also interrupted water dependent birds, animals etc.

5.1.3.2 Attribute - 2: 'Resilience of urban water bodies to face the challenge of climate change impacts'

5.1.3.2.1 Cooling Effect During Summer on Heat Stress of Selected Urban Wetlands

According to field observation, in Study area - 1: Dhanmondi Lake has been performing 'moderately effective resilience' on cooling effect in recent time as surrounding concrete paved area has been increasing day by day to obstruct cooling effect by the water body; has been playing moderately effective role of climate modifier by regulating environmental balance on high temperature, relative humidity and wind etc. recently; due to climate change impacts, aquatic ecosystems are destroying by the rising temperature (heat stress) in the water.

In Study area - 2: Gulshan-Baridhara Lake, has been performing 'moderately effective resilience' as surrounding concrete paved area has been increasing day by day to obstruct cooling effect by the water body; absence of big shaded trees on the Badda bank side; has been playing moderately effective role of climate modifier; due to climate change impacts, aquatic ecosystems are destroying by the rising temperature (heat stress) in the water.

In Study area - 3: Hatirjheel Lake, has been performing 'moderately effective resilience' as surrounding concrete paved area has been increasing day by day to obstruct cooling effect by the water body; has been playing moderately effective role of climate modifier; as this area is a commercial urbanized area, maximum Green House Gas (GHGs) can produce by road transport vehicles and industrial set up that has been emitting by air pollution; heat stress can generate within surrounding area for this reason which can deteriorate the urban environment and address the climate change impacts on this fresh water body as well; due to climate change impacts, aquatic ecosystems are destroying by the rising temperature (heat stress) in the water.

In Study area - 4: Ramna Lake, has been performing 'effective resilience' as huge green canopy of trees, plants, shrubs have been reflecting a green attractive portrait for urban dwellers; this water body can be a good climate modifier in terms of air, temperature, humidity etc. for presence of water courses and huge green vegetation and trees; due to climate change impacts, aquatic ecosystems are destroying by the rising temperature (heat stress) in the water.

In Study area - 5: Diabari Bottola Lake, has been performing 'moderately effective resilience' as surrounding concrete paved area has been increasing day by day to obstruct cooling effect by the water body; absence of big shaded trees on the banks; has been playing moderately effective role of climate modifier; due to climate change impacts, aquatic ecosystems are destroying by the rising temperature (heat stress) in the water.

In Study area - 6: Ashulia urban wetland, in dry season this water body has been performing 'not effective at all' as absence of water in dry season and absence of big shaded trees on the banks. In rainy season 'moderately effective resilience' as maximum depth of water in rainy season; this water body may work moderately in rainy season on air quality improvement function, can play the role of climate modifier by regulating environmental balance on high temperature, relative humidity and wind etc.; as this sub-urban area have less paved concrete areas; due to climate change impacts, aquatic ecosystems are destroying by the rising temperature (heat stress) in the water.

In Study area - 7: Birulia urban wetland, in dry season this water body has been performing 'not effective at all' as absence of water in dry season and absence of big shaded trees on the banks, trees are present only surrounding the Birulia village. In rainy season 'moderately effective resilience' as maximum depth of water in rainy season; this water body may work moderately in rainy season on air quality improvement function, can play the role of climate modifier by regulating environmental balance on high temperature, relative humidity and wind etc.; as this sub-urban area have less paved concrete areas; due to climate change impacts, aquatic ecosystems are destroying by the rising temperature (heat stress) in the water.

From the overall observation in seven study areas, some general problems can occur any time for recent temperature rise in any water courses, these are: climate change impacts on urban freshwater ecosystems which normally caused by the effects of rising Green House Gas (GHG) of Carbon-dy-oxide (CO_2), Methane (CH4) and Nitrous Oxide (N2O) emission in the atmosphere due to unsustainable burning of fossil fuels (coal, oil, natural gas etc.), this Green House effect will later changes and alter temperature and precipitation in the atmosphere; due to high temperature in the atmosphere within present days in Dhaka city, climate change may be significant and that can alter water temperature by increase heat and evapotranspiration and finally Dissolved Oxygen (DO) may decrease in the selected water bodies; for this dissolved oxygen depletion, aquatic flora and fauna as fishes and other aquatic species (reptiles, amphibians, mammals etc.) as well as aquatic whole biodiversity and ecosystem can interrupt. This species depletion directly effects to the food chain and habitat of the freshwater ecosystem; these warming temperatures can disturb habitats of some aquatic species and can move to other places of water body. Other species can be at high risk as well.

5.1.3.2.2 Storage Capacity During Heavy Rainfall on Flood Stress of Selected Urban Wetlands

For active natural drainage, in Study area - 1: Dhanmondi Lake is a large surface water bodies that should accumulate the surface runoff water through different internal drainage channels. It should serve very important hydrologic functions of draining and detaining flood and storm water from a large area of Dhaka city (Figure – 5.25).

Figure – 5.25: Active surface interconnecting natural drainage system for surface and rain water runoff in Dhanmondi Lake areas in dry season (Source: Author personal field observation)

But, according to field observation, in Study area - 1: Dhanmondi Lake has been performing ‘moderately effective resilience’ on storage capacity in recent time as moderate storage capacity during heavy rainy season observed sometimes and bank has been overflowing during heavy rainy season some year (but this do not interrupt the road level activities); drainage problem observed surrounding the water body in recent times some areas especially road no. 27 and road no. 32 areas of Dhanmondi are not working properly with stagnant water of several hours for improper and inadequate drainage problem that increasing water logging during monsoon season normally; waste discharges from some sources creating water logging in surrounding road areas of this lake; urban surface run-off and storm water discharges are carrying suspended particles, which ultimately settle at the bottom of the water body that has been decreasing the depth of this lake in recent years.

In Study area - 2: Gulshan-Baridhara Lake, has been performing ‘moderately effective resilience’ as waste and waste water has been discharging that is creating lower the bed level day by day.

In Study area - 3: Hatirjheel Lake, has been performing ‘moderately effective resilience’ as for inactive natural drainage by overloaded wastes turned this largest surface water body into big obstacles for proper hydrological functioning recently; waste and waste water has been discharging that is creating lower the bed level day by day.

For active natural drainage, in Study area - 4: Ramna Lake, is a large surface water body that accumulates the surface runoff water through surrounding different internal drainage channels (Figure – 5.26).

Figure – 5.26: Large catchment areas for surface and rain water retention capacity in the Ramna Lake in dry season (Source: Author personal field observation)

In Study area - 4: Ramna Lake, has been performing 'effective resilience' as comparatively less water logging and drainage congestion observed in this area; large area for storm and rain water accumulation.

For active natural drainage, in Study area - 5: Diabari Bottola Lake, is a large surface water body that accumulates the surface runoff water through surrounding different internal drainage channels (Figure – 5.27).

Figure – 5.27: Active surface interconnecting natural drainage system for surface and rain water runoff surrounding the Diabari Bottola Lake areas in dry season (Source: Author personal field observation)

In Study area - 5: Diabari Bottola Lake, has been performing 'effective resilience' as effective natural drainage of storm and rain water; large area for storm and rain water accumulation.

In Study area - 6: Ashulia urban wetland, has been performing ‘effective resilience’ as for active natural drainage, this water body is one of the large surface water bodies that accumulate the surface runoff water, rain water and flood water without any obstructions; it serves very important hydrologic function of draining and detaining storm water naturally from a large area of this Ashulia floodplain as well; Ashulia water body is generally a large open rain water catchment area, a flood and a storm water reservoir area (hydrologic function), so, water naturally can drain into this water body easily; therefore, there is no water logging and drainage congestion observed in this area etc (Figure – 5.28).

Figure - 5.28: Seasonal fluctuation of water level during dry and monsoon seasons in the Ashulia urban wetland (Source: Author personal field observation)

For active natural drainage, in Study area - 7: Birulia urban wetland is a large surface water body that accumulates the surface runoff water through surrounding different internal drainage channels without any obstructions (Figure – 5.29).

Figure - 5.29: Seasonal fluctuation of water level during dry and monsoon seasons in same area of the Birulia urban wetland (Source: Author personal field observation)

In Study area - 7: Birulia urban wetland, has been performing 'effective resilience' as based on hydrologic functions, this water body is a large surface water reservoir that can accumulate large amount of flood, storm, rain, surface runoff water etc. naturally; it serves a very important hydrologic function of draining and detaining storm water naturally from a large area of this Birulia floodplain as well; in Birulia water body, as this is a low land of flood plain, water can drain into this water body naturally; therefore, there is no water logging and drainage congestion observed in this area.

From the overall observation in seven study areas, some general problems can occur any time for storage capacity in any water courses, these are: due to high temperature increases, it may change in high intensity of precipitation that can affect flood hazard and surface runoff during monsoon in the selected lakes. An increase or decrease in freshwater flows will also affect by altering excess sediment inputs and nutrient loadings; for this alteration of precipitation regime, biodiversity loss inside lake ecosystem can take place, that will significantly impact aquatic plants and animals at different stages of their life cycles and many invasive aquatic weeds may take place, which have negative and harmful effects on these wetland ecosystem as well; excessive rainfall within short time duration can also enhance organic carbon in the lake ecosystem etc.

5.1.3.2.3 Drought Stress (Water Quantity)

According to field observation, in seven study areas, it has seen that, these water bodies has been performing 'less effective resilience' on drought stress in recent time as all selected urban water bodies observed water tables lower and almost dried in Study area – 6 and 7 as Ashulia and Birulia study areas during dry season for recent high atmospheric temperature, decreased precipitation rate and high evapotranspiration; may likely increase the risk of drought and may decrease water availability in the warm summer season by lowering ground water table that impacted severely as well; for this drought stress for climate change, these freshwaters based aquatic vegetation, fishes, wildlife and other species that are always depend on the water body may be under threat; maximum of these water bodies found polluted enough recently for interrupt filter waste and waste water, so infiltration system cannot be performed properly to get the fresh and clean underground water in recent times; as much polluted, this polluted water can be transmitted contamination up to ground aquifer level easily.

5.1.3.2.4 Water Quality

According to field observation, in Study area - 1: Dhanmondi Lake, water body has been performing 'less effective resilience' on water quality; in Study area - 2, 3, 6 and 7 as Gulshan-Baridhara Lake, Hatirjheel Lake, Ashulia urban wetland and Birulia urban wetland with 'not effective at all' and Study area - 4 and 5 as Ramna Lake and Diabari Bottola Lake with 'moderately effective resilience' on water quality as in the selected lakes, during high intensity of precipitation, over polluted sewage, waste water from surface runoff can increase excess nutrients load, sediment load, phosphate load, nitrate load, ammonia load and other pollutants that have been declining the overall quality of water day by day.

5.1.3.3 Attribute - 3: 'Contribution for community livelihood'

In Study area - 1: Dhanmondi Lake, has been used widely for different community livelihood activities as follows (Figure – 5.30, 5.31, 5.32, 5.33, 5.34).

Figure – 5.30: Recreational/sports/angling fishing by the 'Motsho Club' members (in 1, 2 and 3rd pictures) in Dhanmondi Lake and big and small fishes' areas have been divided by the net separator in dry season (in 4th picture) (Source: Author personal field observation)

Figure – 5.31: Fish farmers has been working for pull of submerged wastes and dry leaves with some non-engine boats those have been appointed from 'Motsho Club' in Dhanmondi Lake in dry season (Source: Author personal field observation)

Different types of peoples have been gathering for different time of the day and night time for recreation from different areas of the city in this lake. This Dhanmondi Lake is used extensively for boating as recreation (Figure – 5.32).

Figure – 5.32: Dhanmondi Lake has been used extensively for paddle boating on recreational purposes and direct livelihood (wetland resources dependent) activities in dry season (Source: Author personal field observation)

Some of temporary and permanent restaurants are available in this urban wetland for urban dweller’s recreational purpose and for indirect livelihood activities (Figure – 5.33).

Figure – 5.33: Indirect livelihood and recreational activities of some temporary and permanent restaurants surrounding the Dhanmondi Lake in dry season (Source: Author personal field observation)

On the perspective of indirect livelihood activities in this water body, different types of people from different professions have been bearing their indirect livelihood in this lake side's area (Figure – 5.34).

Figure – 5.34: Different vendors of various professions have been working in Dhanmondi Lake area for their indirect livelihood activities in dry season (Source: Author personal field observation)

According to field observation, in Study area - 1: Dhanmondi Lake, has been performing 'moderately effective contribution' for community livelihood' in recent time as wetland resource dependent livelihood is almost restricted and not open to local public; water quality has been declining by surrounding pollution for angling activities recently; absence of commercial fish cultivation activities; restricted for agricultural activities; absence of water transport activities; only indirect livelihood are present (vendors, restaurants, paddle boat etc. activities).

In Study area - 2: Gulshan-Baridhara Lake, has been used widely for different community livelihood activities as follows (Figure – 5.35, 5.36).

Figure – 5.35: Direct livelihood activities of commercial fish cultivation arrangement of fishermen those leased by RAUK in the Gulshan-Baridhara Lake area in dry season (Source: Author personal field observation)

On the perspective of livelihood activities in this water body, different types of people from different professions have been bearing their indirect livelihood surrounding Gulshan-Baridhara Lake (Figure – 5.36).

Figure – 5.36: Different vendors of various professions have been working surrounding the Gulshan-Baridhara Lake areas for their indirect livelihood activities in dry season (Source: Author personal field observation)

In Study area - 2: Gulshan-Baridhara Lake, has been performing ‘less effective contribution’ as wetland resource dependent livelihood is less, restricted and not open to local public; water is not good for any use recently that seriously hampering commercial fishing activities seriously; restricted for agricultural activities; absence of water transport activities.

In Study area - 3: Hatirjheel Lake, has been used widely for different community livelihood activities as follows (Figure – 5.37, 5.38, 5.39).

Figure – 5.37: Water taxies for transportation and paddle boating for recreation has been playing a vital direct livelihood value in Hatirjheel Lake in dry season (Source: Author personal field observation)

Figure – 5.38: Different big and small restaurants for visitor’s recreation has been playing an indirect livelihood activity in Hatirjheel Lake in dry season (Source: Author personal field observation)

Figure – 5.39: Different floating vendors activities has been playing as indirect livelihood value surrounding Hatirjheel Lake in dry season (vendors are not allowed in water body areas) (Source: Author personal field observation)

In Study area - 3: Hatirjheel Lake, has been performing ‘less effective contribution’ as wetland resource dependent livelihood is less, restricted and not open to local public; water is not good for any use; absence of commercial fish cultivation activities; restricted for agricultural activities; restricted for vendors.

In Study area - 4: Ramna Lake, has been less used for different community livelihood activities as follows (Figure – 5.40, 5.41, 5.42, 5.43).

Figure – 5.40: Angling by the angler in the Ramna Lake in dry season (Source: Author personal field observation)

Figure – 5.41: Indirect livelihood and recreational activities of a permanent restaurants besides the Ramna Lake in dry season (Source: Author personal field observation)

Figure – 5.42: Indirect livelihood activities of cleaning and washing in the Ramna Lake area in dry season (Source: Author personal field observation)

Figure – 5.43: Only bottle water vendors and flower sellers were allowed for working surrounding this Ramna Lake for their indirect livelihood activities in dry season (but recently this activity also restricted) (Source: Author personal field observation)

In Study area - 4: Ramna Lake, has been performing ‘not effective at all’ as wetland resource dependent livelihood is almost restricted and not open to local public; absence of commercial fish cultivation activities; restricted for agricultural activities; absence of water transport activities; restricted for vendors; very less participation on livelihood activities by the public.

In Study area - 5: Diabari Bottola Lake, has been used widely for different community livelihood activities as follows (Figure – 5.44, 5.45, 5.46, 5.47).

Figure – 5.44: Direct livelihood as agricultural activities by the farmers besides the bank of the Diabari Bottola Lake and lake water have been using directly for irrigation purposes in dry season (Source: Author personal field observation)

Figure – 5.45: Direct livelihood as commercial fish cultivation by the lease holders (in pictures fish areas have been divided by net separator of individual fish lease holder) in the Diabari Bottola Lake in dry season (Source: Author personal field observation)

Figure – 5.46: Direct livelihood as paddle boating for recreational purposes in the Diabari Bottola Lake in dry season (Source: Author personal field observation)

Figure – 5.47: Indirect livelihood activities of different professions surrounding the Diabari Bottola Lake areas in dry season (Source: Author personal field observation)

In Study area - 5: Diabari Bottola Lake, has been performing 'moderately effective contribution' as some of wetland resource dependent livelihood is present, but restricted for local public; presence of commercial fish cultivation activities; presence of some agricultural activities on the bank; absence of water transport activities; people presence is less for security and new developed area; some indirect livelihoods are present (vendors, nurseries, paddle boat etc. activities); economic profit of vendors is less for less people presence and safety.

In Study area - 6: Ashulia urban wetland, has been used widely for different community livelihood activities as follows (Figure – 5.48, 5.49, 5.50, 5.51, 5.52, 5.53, 5.54).

Figure – 5.48: High agricultural value (direct use value of wetland) by cultivation of paddy and others different crops in Ashulia urban wetland area during dry season (Source: Author personal field observation)

Figure – 5.49: Cultivation of fodders for domestic animals are available that have economic value in Ashulia wetland area during dry season (Source: Author personal field observation)

Figure – 5.50: Direct livelihood activities of fishing by local people during monsoon in Ashulia urban wetland (Source: Author personal field observation)

Figure – 5.51: Fishing (direct use value of wetland) in Ashulia study area during dry season (Source: Author personal field observation)

Figure – 5.52: Water transport (direct use value of wetland) plays a vital role for local city inhabitants in Ashulia water body area during dry and monsoon season (Source: Author personal field observation)

There is BIWTA recognized one landing station observed as ‘Ashulia Landing Station’ in this study area for broad level transportation station or ghat (Figure – 5.53).

Figure – 5.53: BIWTA recognized one landing station as ‘Ashulia Landing Station’ in Ashulia study area during monsoon season (Source: Author personal field observation)

Originally, Ashulia urban wetland is aesthetically pleasant recreational site (direct use value) that changes with different seasons. During rainy (monsoon) season, panoramic view of this vast waterscape of Ashulia is well attracted by the city inhabitants that enhance tourist activities day by day. The same wetlands in the winter turned into vast green paddy and others vegetables fields during winter. Many city residents visit this place year-round for recreation. The attractive view of adjacent Turag River and vast paddy fields of Ashulia make it a popular tourist spot and is one of the nicest and most romantic places nearby Dhaka city. Natural beauty of the Ashulia always attracts visitors especially in the rainy season. Boat riding is most common recreation at that time. Many floating restaurants are visible in near to Ashulia wetland area for recreational purpose (Figure – 5.54).

Figure – 5.54: Aesthetically pleasant recreational site in Ashulia study area in monsoon season (Source: Author personal field observation)

In Study area - 6: Ashulia urban wetland, has been performing ‘moderately effective contribution’ in dry season and ‘less effective contribution’ in monsoon season as water is not good for any direct use as agriculture and fishing; economic profit has been declining from direct livelihood.

In Study area - 7: Birulia urban wetland, has been used widely for different community livelihood activities as follows (Figure – 5.55, 5.56, 5.57).

Figure - 5.55: Direct livelihood value as agricultural activities of different crops cultivation during dry season in Birulia study area (Source: Author personal field observation)

Figure - 5.56: Direct livelihood value as fishing during dry seasons (maximum fish availability in rainy season) in Birulia study area (Source: Author personal field observation)

Figure - 5.57: Direct livelihood value as water transport plays a vital role for local inhabitants in Birulia wetland during all the seasons (Source: Author personal field observation)

In Study area - 7: Birulia urban wetland, has been performing ‘moderately effective contribution’ in dry season and ‘less effective contribution’ in monsoon season as water is not good for any direct use as agriculture and fishing; economic profit has been declining from direct livelihood etc.

5.1.3.4 Attribute - 4: 'Adequacy of the policy regime'

From the literature review we saw that, there are a lot of existing policies, laws, acts, regulations, strategies which have been developed by the Bangladesh Government on the wetland sectors in the country. But, on the urban wetland sectors, there are still lack of proper sustainable policies on different factors with inconducive in nature. Another way, there is a huge gap between existing policies and implementation of policies that have been unsustainable for appropriate urban wetland management still now. Therefore, there is urgent need to think about urban wetland management in the capital with sustainable policies and their proper implementations for the long-term economic development in the country.

According to the field observation, it has seen that, In Study area - 1: Dhanmondi Lake, urban wetland has been performing 'moderately effective contribution' for implementation of policy regime as lack of implementation of policies, laws on source pollution and water quality improvement, lack of implementation of laws on public pollution of lake water by throwing wastes.

In Study area - 2: Gulshan-Baridhara Lake, urban wetland has been performing 'less effective contribution' for implementation of policy regime as lack of enforcement of laws on water quality improvement, pollution etc., lack of enforcement on surrounding sewerage, industrial and other urban waste pollution, lack of enforcement of laws on public pollution of lake water by throwing wastes.

In Study area - 3: Hatirjheel Lake, urban wetland has been performing 'less effective contribution' for implementation of policy regime as lack of implementation of laws on water quality improvement pollution etc., lack of enforcement on surrounding sewerage, industrial and other urban waste pollution, lack of enforcement of laws on public pollution of lake water by throwing wastes, need more enforcement of laws on security function, need more enforcement of laws on presence of unexpected people sometimes.

In Study area - 4: Ramna Lake, urban wetland has been performing 'effective contribution' for implementation of policy regime as effective enforcement of laws, policies for pollution, water quality improvement function etc., effective enforcement on surrounding sewerage, industrial and other urban waste pollution control, need more enforcement on security function (improving).

In Study area - 5: Diabari Bottola Lake, urban wetland has been performing 'effective contribution' for enforcement of policy regime as effective enforcement of laws, policies for pollution, water quality improvement function etc., effective enforcement on surrounding sewerage, industrial and other urban waste pollution control, lack of implementation of laws for security issue after 6 pm (recently comparatively improving than before), some waste pollution observed by the public on the bank of water body by throwing wastes etc.

In Study area - 6: Ashulia urban wetland, urban wetland has been performing 'not effective at all' for implementation of policy regime as no implementation of policies on pollution by the dyeing factories and other industries still now, no restriction of pollution on domestic, construction and other wastes by the public, lack of enforcement on surrounding sewerage pollution, encroachment should be stopped by the proper laws as 'Joladhar Songrokkon Ain' and others.

In Study area - 7: Birulia urban wetland, urban wetland has been performing ‘not effective at all’ for implementation of policy regime as no implementation of policies on pollution by the industries, factories etc., no restriction of pollution on domestic, construction and other wastes by the public, lack of enforcement on surrounding sewerage pollution etc.

5.1.3.5 Attribute - 5: ‘Local acceptance and credibility of the role of relevant institutions’

According to field observation in Study area - 1: Dhanmondi Lake, relevant institutions has been performing their role with ‘moderately effective contribution’ on this urban wetland as lack of management on water pollution observed still now (water quality declining), lack of management on awareness about environmental conservation and management by the public and relevant authorities, people from different area visited this lake frequently all the year round, but this can bring management problem to the relevant authorities for sustainable maintenance of this neighborhood-based lake.

In Study area - 2: Gulshan-Baridhara Lake, relevant institutions have been performing their role with ‘less effective contribution’ on this urban wetland as lack of management on water quality improvement, pollution etc., lack of management on surrounding sewerage, industrial and other urban waste pollution control, lack of management on awareness about environmental conservation and management by the public and relevant authorities, lack of maintenance.

In Study area - 3: Hatirjheel Lake, relevant institutions have been performing their role with ‘less effective contribution’ on this urban wetland as lack of management on water quality improvement, pollution etc., lack of management on surrounding sewerage, industrial and other urban waste pollution control, lack of management on awareness about environmental conservation and management by the public and relevant authorities, but strict management by the Bangladesh Army for different issues have been observed as well.

In Study area - 4: Ramna Lake, relevant institutions have been performing their role with ‘effective contribution’ on this urban wetland as effective management of pollution, water quality improvement function etc., effective maintenance and management on surrounding sewerage, industrial and other urban waste pollution control, effective management on awareness about environmental conservation and management by the public and relevant authorities, need more control on security function (improving).

In Study area - 5: Diabari Bottola Lake, relevant institutions have been performing their role with ‘effective contribution’ on this urban wetland as effective management of pollution, water quality improvement function etc., effective maintenance and management on surrounding sewerage, industrial and other urban waste pollution control, effective management on awareness about environmental conservation and management by the public and relevant authorities, but some waste pollution by the visitors on the banks have been still observed in this area that reflect lack of awareness of public and relevant authorities, much lack of security.

In Study area - 6: Ashulia urban wetland, relevant institutions have been performing their role with ‘not effective at all’ on this urban wetland as no contribution on conservation and management of the water body, limited resources and power to handle all wetland connecting issues, lack of management from higher Government authorities towards conservation of the urban wetland, lack of management on water quality improvement, pollution etc., lack of management on surrounding sewerage, industrial and other urban waste pollution control, lack of awareness about environmental conservation and management by the public and relevant authorities.

In Study area - 7: Birulia urban wetland, relevant institutions have been performing their role with ‘not effective at all’ on this urban wetland as no contribution on conservation and management of water body, limited resources and power to handle all wetland connecting issues, lack of management from higher Government authorities towards conservation of the urban wetland, lack of management on water quality improvement, pollution etc., lack of management on surrounding sewerage, industrial and other urban waste pollution control, lack of awareness about environmental conservation and management by the public and relevant authorities.

5.1.3 Challenges of Urban Wetland Management and Use according to the Urban Wetland Sustainability Framework (UWSF) Model – 1 of Selected Urban Wetlands by the Author Personal Observation

This section discussed about the challenges of urban wetland management and use according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' of selected urban wetlands by the author personal observation that followed the second objective and the second research question that have been developed in this research.

(1) For Attribute - 1: 'Contribution for biodiversity conservation and enhancement', main challenges of urban wetland management and use identified as bad water quality by pollution through human and natural activities, seasonal difference of water level interrupting biodiversity, fish mortality, unplanned urban development, unplanned land use, encroachment, rapid population pressure, climate change impacts, less importance has been giving on the value of biodiversity and ecosystem conservation, less awareness on conservation, lack of community and stakeholder involvement on conservation and management, degradation of ground water ecology etc.

(2) For Attribute - 2: 'Resilience of urban water bodies to face the challenge of climate change impacts', challenges of urban wetland management and use observed on 'cooling effect' are as increase of over paved concrete areas in the city that are producing heat, urban development, atmospheric temperature getting high day by day, heat absorbing capacity of wetlands are reducing for filling and encroachment of wetland areas, siltation, destroying aquatic ecosystems by decreasing Dissolved Oxygen (DO), depletion of species, habitat loss and degradation etc.

(3) For Attribute - 2, challenges observed on 'storage capacity' are as urban development, unplanned land use, filling and encroachment of wetland areas, insufficient capacity of water bodies to store water, siltation, bed level reduction of water bodies through accumulation of sludge, lack of proper functioning of drainage infrastructures, improper drainage connection and capacity etc.

(4) For Attribute - 2, challenges observed on 'drought stress' are as lower water level in winter and summer season, threat for aquatic vegetation, fishes, wildlife and other species, reduction of ground water availability in the warm summer season, risk of earthquake etc.

(5) For Attribute - 2, challenges observed on 'water quality' are as high pollution load during high intensity of precipitation by climate change impacts.

(6) For Attribute - 3: 'Contribution for community livelihood', challenges observed as livelihood restrictions on the urban context, less scope on wetland resource dependent livelihood for local poor community people, most demanded local fresh water fishes have been replaced by culture and less demanded fish species for water quality degradation, pollution, urbanization and climate change impacts etc.

(7) For Attribute - 4: 'Adequacy of the policy regime', challenges observed are as lack of enforcement of policies, laws, regulations on source pollution and water quality improvement, lack of implementation of laws on public pollution of lake water by throwing wastes, lack of enforcement of policies on surrounding domestic, construction, sewerage, industrial and other urban waste pollution, encroachment of urban wetlands should be stopped by the proper laws as ‘Joladhar Songrokkon Ain’ and others, lack of implementation of policies on security and safety functions, lack of enforcement of policies on presence of unexpected people sometimes in the study areas.

(8) For Attribute - 5: ‘Local acceptance and credibility of the role of relevant institutions’, some challenges observed as lack of sustainable conservation, maintenance and management of urban wetlands, lack of stakeholder perceptions on management, lack of community people involvement on planning, conservation and management, lack of proper waste management, lack of thinking of wetland connecting values and services, lack of coordination among all relevant organizations, lack of proper maintenance of existing drainage connections, lack of management on water quality improvement, pollution etc., lack of management on surrounding domestic, construction, sewerage, industrial and other urban waste pollution control, lack of management on awareness about environmental conservation and management by the public and relevant authorities, lack of management on security function, in some urban wetlands’ areas, there is no contribution on conservation and management at all, limited resources and power to handle all wetland connecting issues, lack of management from higher Government authorities towards conservation of the urban wetland etc.

Following pictures have been showing different challenges of urban wetland management and use of selected urban wetlands by the author personal observation (Figure – 5.58, 5.59, 5.60, 5.61, 5.62, 5.63, 5.64, 5.65, 5.66, 5.67, 5.68).

Figure – 5.58: Floating mats of wastes has been polluted the water of Dhanmondi Lake that interrupting enhancement of biodiversity and ecological stability, causing serious threats on fish, other aquatic lives and finally ground water ecology in dry season (Source: Author personal field observation)

Figure – 5.59: Random domestic, construction wastes, other wastes and waste water have been dumping and discharging on both sides of the Gulshan-Baridhara Lake area in dry season (Source: Author personal field observation)

Figure – 5.60: Dumping of domestic and industrial solid wastes on the bank of the Hatirjheel Lake in dry season (Source: Author personal field observation)

Figure – 5.61: Effluent with deep greenish contaminated and awful odor water from the Hatirjheel Lake area in dry season (Source: Author personal field observation)

Figure – 5.62: Dumping of solid wastes on the bank of the Ashulia water body in dry season (Source: Author personal field observation)

Figure – 5.63: Unplanned industrialization on the bank of the Ashulia water body in dry season (Source: Author personal field observation)

Figure – 5.64: Coal dumping on the bank side of the Ashulia water body which threating the floral and faunal species in dry season (Source: Author personal field observation)

Figure - 5.65: Smoke generated from brick kiln industries has adverse impact on productivity of agricultural land and surrounding environment during dry season of the Ashulia wetland (Source: Author personal field observation)

Figure - 5.66: Encroachment by Jamuna Group in Ashulia urban wetland area in dry season (Source: Author personal field observation)

Figure – 5.67: Invasion of water hyacinth aquatic plants and discharge of waste materials from surrounding dying factories in Ashulia urban wetland area in monsoon season (Source: Author personal field observation)

Figure - 5.68: Invade by water hyacinth and other aquatic weeds by over pollution in Birulia study area (during dry season) (Source: Author personal field observation)

According to Chapter – IV, current scenario, existing role of urban wetlands according to 'Urban Wetland Sustainability Framework (UWSF) Model – 1' on the global context has been identified as loss of biodiversity, disruption on the resilience of climate change impacts for urban wetlands, degradation of wetland-based livelihood activities for different challenges, maximum urban wetlands has been acting as recreational tourism spaces, educational spaces etc., active participation of relevant institutions on the restoration, management of maximum urban wetlands on the global context, but, there are different challenges that need to be resolved etc. From this information, we can see that, there are some similarity and dissimilarity with the identified present research current scenario, existing role of selected urban wetlands in the capital according to study area stakeholder perceptions, institutional stakeholder expert perceptions and author personal field observation.

Main challenges on management and use of urban wetlands according to 'Urban Wetland Sustainability Framework (UWSF) Model – 1' on the global context (from Chapter – IV) has been identified as urban and economic development, severe water pollution from urban waste and effluent, fish mortality, agricultural development, eutrophication, reduction of terrestrial biodiversity for the extensive decrease in forestland, alteration of fresh water flow, shrinkage of water-spread area, reduction of water storage capacity, land use change, siltation, sedimentation, degradation of the drainage basin, dry condition of wetland during winter and summer, degradation of ground water ecology, over population, urban wetland-based community livelihood has been affected by different reasons, wetland based resources depletion, limited scope on livelihood occupation and opportunities, lack of management of the relevant organization, lack of institutional mechanism to regulate the common resources resulted in unsustainable and unbalanced resource distribution and use, lack of public concern etc. From this information, we can see that, there are some similarity and dissimilarity with the identified present research challenges on management and use of selected urban wetlands in the capital according to study area stakeholder perceptions, institutional stakeholder expert perceptions and author personal field observation.

Again, According to Chapter – IV, current scenario, existing role of urban wetlands according to 'Urban Wetland Sustainability Framework (UWSF) Model – 1' on the Dhaka city context has been identified as severe degradation of biodiversity, climate change impacts is one of the recent threats for urban wetlands in the city, interruption of livelihood activities, little access to legal and institutional support in some area etc. From this information, we can see that, there are some similarity and dissimilarity with the identified present research current scenario, existing role of selected urban wetlands in the capital according to study area stakeholder perceptions, institutional stakeholder expert perceptions and author personal field observation.

Main challenges on management and use of urban wetlands according to 'Urban Wetland Sustainability Framework (UWSF) Model – 1' on the Dhaka city context (from Chapter – IV) has been identified as high levels of organic and inorganic anthropogenic pollution, deterioration of wetland water quality by industrial, sewerage and other toxic urban waste and waste water accumulation in the urban wetland, fish killing incidence, lack of proper sewer network, very low concentration of Dissolved Oxygen (DO) concentration and other parameters, unplanned urban economic development, water logging, improper waste collection and disposal, lack of proper existing drainage infrastructure, sedimentation by urban effluent, reduction of water retention capacity of urban wetlands, reduction of water level, rise of air and water temperature, nature of development which conflicts with the neighborhood environment etc. From this information, we can see that, there are some similarity and dissimilarity with the identified present research challenges on management and use of selected urban wetlands in the capital according to study area stakeholder perceptions, institutional stakeholder expert perceptions and author personal field observation. Therefore, current status, existing role and challenges on management and use of any urban wetland in any area can differ on the context.

5.2 Concluding Remarks

This chapter discussed the results of current scenario, existing role, challenges of urban wetland management and use and recommendations for future improvement on sustainable conservation and management of selected urban wetlands that extracted from study area stakeholder perceptions, from institutional stakeholder expert's perceptions and from author personal field observation according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1'.

CHAPTER - VI

FINDINGS AND ANALYSIS - 3: WATER QUALITY ASSESSMENT IN STUDY AREA

This chapter discussed the results of water quality parameter assessment in study areas that followed by the third objective and third research question of the research.

6.1 Water Quality Assessment in Study Area

This section of the research identified the results of the water quality parameters test that have been discussed before in the Chapter - III: Methodology and Study Area. This chapter tried to identified the third research question answers. The research questions is **(3)** what are the results of water quality parameter assessment on selected urban wetlands for identifies aquatic biodiversity and ecosystem conservation capabilities?

6.1.1 Results of Water Quality Assessment in Study Area

Total two (02) samples of water (500 ml) have been collected from seven study areas that covering month of October, November and December 2020 and tested in the Department of Environment (DoE) laboratory. For assessment and monitoring the water quality of selected urban wetlands, total ten (10) nos. water parameters such as Temperature, pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Turbidity, Nitrate-Nitrogen (NO_3-N), Phosphate (PO_4), Total Dissolved Solid (TDS) and Electrical Conductivity (EC) etc. were examined for water of each sampling point and sample to monitor the level of these parameters where it exceed or within the permissible limit of Environmental Quality Standard (EQS) for aquatic biodiversity conservation that has been followed by the DoE. All tested sample results have shown in detail within Appendix – 3.

6.1.1.1 Water Temperature

From the results it was found that, in the month of October 2020, in Dhanmondi Lake, Water Temperature of two water samples varied from 19.6 to 19.2 °C within the EQS limit (20 to 30°C); in Gulshan-Baridhara Lake, varied from 19.5 to 19.7 °C within the EQS limit; in Hatirjheel Lake, varied from 19.5 to 19.8 °C within the EQS limit; in Ramna Lake, varied from 19.4 to 19.5 °C within the EQS limit; in Bottola Dia Bari Lake, varied from 19.4 to 19.6 °C within the EQS limit; in Ashulia urban wetland, varied from 19.6 to 19.5 °C within the EQS limit; in Birulia urban wetland, varied from 19.8 to 19.8 °C within the EQS limit.

In the month of November 2020, in Dhanmondi Lake, Water Temperature of two water samples varied from 23.6 to 23.4 °C within the EQS limit (20 to 30°C); in Gulshan-Baridhara Lake, varied from 23.3 to 23.7 °C within the EQS limit; in Hatirjheel Lake, varied from 23.9 to 23.6 °C within the EQS limit; in Ramna Lake, varied from 23.0 to 23.2 °C within the EQS limit; in Bottola Dia Bari Lake, varied from 23.1 to 23.2 °C within the EQS limit; in Ashulia urban wetland, varied from 23.5 to 23.7 °C within the EQS limit; in Birulia urban wetland, varied from 23.9 to 23.8 °C within the EQS limit.

In the month of December 2020, in Dhanmondi Lake, Water Temperature of two water samples varied from 16.7 to 17.4 °C within the EQS limit (20 to 30°C); in Gulshan-Baridhara Lake, varied from 18.6 to 18.7 °C within the EQS limit; in Hatirjheel Lake, varied from 16.8 to 16.8 °C within the EQS limit; in Ramna Lake, varied from 18.8 to 18.2 °C within the EQS limit; in Bottola Dia Bari Lake, varied from 18.1 to 18.3 °C within the EQS limit; in Ashulia urban wetland, varied from 18.0 to 18.0 °C within the EQS limit; in Birulia urban wetland, varied from 18.3 to 18.1 °C within the EQS limit.

From the above values, it was identified that, in Dhanmondi Lake, the lowest Water Temperature was recorded in December (16.7 °C) at sample location - 01 and within the EQS limit (20 to 30°C) and the highest was recorded in November (23.6 °C) at sample location - 01 and within the EQS limit; In Gulshan-Baridhara Lake, the lowest temperature was recorded in December (18.6 °C) at sample location - 01 and within the EQS limit and the highest was recorded in November (23.7 °C) at sample location - 02 and within the EQS limit; In Hatirjheel Lake, the lowest temperature was recorded in December (16.8 °C) at sample location - 01 & 02 and within the EQS limit and the highest was recorded in November (23.9 °C) at sample location - 01 and within the EQS limit; in Ramna Lake, the lowest temperature was recorded in December (18.2 °C) at sample location - 02 and within the EQS limit and the highest was recorded in November (23.2 °C) at sample location - 02 and within the EQS limit; In Bottola Dia Bari Lake, the lowest temperature was recorded in December (18.1 °C) at sample location - 01 and within the EQS limit and the highest was recorded in November (23.2 °C) at sample location - 02 and within the EQS limit; In Ashulia urban wetland, the lowest temperature was recorded in December (18.0 °C) at sample location - 01 & 02 and within the EQS limit and the highest was recorded in November (23.7 °C) at sample location - 02 and within the EQS limit; In Birulia urban wetland, the lowest temperature was recorded in December (18.1 °C) at sample location - 02 and within the EQS limit and the highest was recorded in November (23.9 °C) at sample location - 01 and within the EQS limit. Following (Figure – 6.1) shows the Water Temperature level in study area across three months for sample 1 and 2.

In Dhanmondi Lake, the average Water Temperature was recorded 19.98 °C, in Gulshan-Baridhara Lake, was recorded 20.58 °C, in Hatirjheel Lake, was recorded 20.07 °C, in Ramna Lake, was recorded 20.35 °C, in Bottola Dia Bari Lake, was recorded 20.28 °C, in Ashulia urban wetland, was recorded 20.38 °C, in Birulia urban wetland, was recorded 20.62 °C which are within the EQS limit (20 to 30°C) and suitable for fisheries (Figure - 6.2).

6.1.1.2 pH

In the month of October 2020, in Dhanmondi Lake, pH of two water samples varied from 7.53 to 7.42 within the EQS limit (6.5 to 8.5 for fisheries) of alkaline water which is sustainable for fisheries; in Gulshan-Baridhara Lake, pH of two water samples varied from 7.46 to 7.37 within the EQS limit of alkaline water which is sustainable for fisheries; in Hatirjheel Lake, pH of two water samples varied from 7.38 to 7.40 within the EQS limit of alkaline water which is sustainable for fisheries; in Ramna Lake, pH of two water samples varied from 7.58 to 7.60 within the EQS limit of alkaline water which is sustainable for fisheries; in Bottola Dia Bari Lake, pH of two water samples varied from 7.86 to 7.83 within the EQS limit of alkaline water which is sustainable for fisheries; in Ashulia urban wetland, pH of two water samples varied from 7.51 to 7.44 within the EQS limit of alkaline water which is sustainable for fisheries; in Birulia urban wetland, pH of two water samples varied from 7.50 to 7.41 within the EQS limit of alkaline water which is sustainable for fisheries.

In the month of November 2020, in Dhanmondi Lake, pH of two water samples varied from 7.46 to 7.47 within the EQS limit (6.5 to 8.5 for fisheries) of alkaline water which is sustainable for fisheries; in Gulshan-Baridhara Lake, pH of two water samples varied from 7.03 to 7.04 within the EQS limit of alkaline water which is sustainable for fisheries; in Hatirjheel Lake, pH of two water samples varied from 7.35 to 7.37 within the EQS limit of alkaline water which is sustainable for fisheries; in Ramna Lake, pH of two water samples varied from 6.94 to 7.31 within the EQS limit of alkaline water which is sustainable for fisheries; in Bottola Dia Bari Lake, pH of two water samples varied from 7.31 to 7.28 within the EQS limit of alkaline water which is sustainable for fisheries; in Ashulia urban wetland, pH of two water samples varied from 7.45 to 7.43 within the EQS limit of alkaline water which is sustainable for fisheries; in Birulia urban wetland, pH of two water samples varied from 7.29 to 7.31 within the EQS limit of alkaline water which is sustainable for fisheries.

In the month of December 2020, in Dhanmondi Lake, pH of two water samples varied from 6.93 to 6.93 within the EQS limit (6.5 to 8.5 for fisheries) of alkaline water which is sustainable for fisheries; in Gulshan-Baridhara Lake, pH of two water samples varied from 7.27 to 7.31 within the EQS limit of alkaline water which is sustainable for fisheries; in Hatirjheel Lake, pH of two water samples varied from 7.27 to 7.24 within the EQS limit of alkaline water which is sustainable for fisheries; in Ramna Lake, pH of two water samples varied from 7.52 to 7.26 within the EQS limit of alkaline water which is sustainable for fisheries; in Bottola Dia Bari Lake, pH of two water samples varied from 7.51 to 7.53 within the EQS limit of alkaline water which is sustainable for fisheries; in Ashulia urban wetland, pH of two water samples varied from 7.25 to 7.26 within the EQS limit of alkaline water which is sustainable for fisheries; in Birulia urban wetland, pH of two water samples varied from 7.22 to 7.26 within the EQS limit of alkaline water which is sustainable for fisheries.

From the above values, it was identified that, in Dhanmondi Lake, the lowest pH was recorded in December (6.93) at sample location - 01 & 02 and within the EQS limit (6.5 to 8.5 for fisheries) and the highest was recorded in October (7.53) at sample location - 01 and within the EQS limit; in Gulshan-Baridhara Lake, the lowest pH was recorded in November (7.03) at sample location - 01 and within the EQS limit and the highest was recorded in October (7.46) at sample location - 01 and within the EQS limit; in Hatirjheel Lake, the lowest pH was recorded in December (7.24) at sample location - 02 and within the EQS limit and the highest was recorded in October (7.40) at sample location - 02 and within the EQS limit; in Ramna Lake, the lowest pH was recorded in November (6.94) at sample location - 01 and within the EQS limit and the highest was recorded in October (7.60) at sample location - 02 and within the EQS limit; in Bottola Dia Bari Lake, the lowest pH was recorded in November (7.28) at sample location - 02 and within the EQS limit and the highest was recorded in October (7.86) at sample location - 01 and within the EQS limit; in Ashulia urban wetland, the lowest pH was recorded in December (7.25) at sample location - 01 and within the EQS limit and the highest was recorded in October (7.51) at sample location - 01 and within the EQS limit; in Birulia urban wetland, the lowest pH was recorded in December (7.22) at sample location - 01 and within the EQS limit and the highest was recorded in October (7.50) at sample location - 01 and within the EQS limit. Following (Figure – 6.3) shows the pH level in study area across three months for sample 1 and 2.

In Dhanmondi Lake, the average pH was recorded 7.29, in Gulshan-Baridhara Lake, was recorded 7.25, in Hatirjheel Lake, was recorded 7.34, in Ramna Lake, was recorded 7.37, in Bottola Dia Bari Lake, was recorded 7.55, in Ashulia urban wetland, was recorded 7.39, in Birulia urban wetland, was recorded 7.33 which are within the EQS limit (6.5 to 8.5) is suitable for fisheries indicating alkaline water in maximum urban wetlands (Figure - 6.4).

6.1.1.3 Dissolved Oxygen (DO)

In the month of October 2020, in Dhanmondi Lake, Dissolved Oxygen (DO) of two water samples varied from 6.70 to 6.80 mg/L, within the EQS limit (>=5 mg/L for fisheries) with lower organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Gulshan-Baridhara Lake, DO of two water samples varied from 6.10 to 6.00 mg/L, within the EQS limit with medium organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Hatirjheel Lake, DO of two water samples varied from 5.60 to 5.80 mg/L, within the EQS limit with medium organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Ramna Lake, DO of two water samples varied from 8.40 to 8.50 mg/L, within the EQS limit that indicating good quality of water with lower organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Bottola Dia Bari Lake, DO of two water samples varied from 8.80 to 8.60 mg/L, within the EQS limit that indicating good quality of water with lower organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Ashulia urban wetland, DO of two water samples varied from 7.50 to 7.30 mg/L, within the EQS limit with lower organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Birulia urban wetland, DO of two water samples varied from 8.00 to 7.90 mg/L, within the EQS limit with lower organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species.

In the month of November 2020, in Dhanmondi Lake, DO of two water samples varied from 6.00 to 10.0 mg/L, within the EQS limit (>_5 mg/L for fisheries) that indicating good quality of water with lower organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Gulshan-Baridhara Lake, DO of two water samples varied from 0.60 to 0.00 mg/L, not within the EQS limit with higher organic and inorganic pollutants that is not suitable for fisheries and other aquatic organisms or species; in Hatirjheel Lake, DO of two water samples varied from 3.80 to 0.00 mg/L, not within the EQS limit with higher organic and inorganic pollutants that is not suitable for fisheries and other aquatic organisms or species; in Ramna Lake urban water body, DO of two water samples varied from 6.70 to 8.00 mg/L, within the EQS limit that indicating good quality of water with lower organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Bottola Dia Bari Lake, DO of two water samples varied from 3.50 to 2.60 mg/L, not within the EQS limit with higher organic and inorganic pollutants that is not suitable for fisheries and other aquatic organisms or species; in Ashulia urban wetland, DO of two water samples varied from 5.80 to 6.40 mg/L, within the EQS limit with medium organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Birulia urban wetland, DO of two water samples varied from 4.30 to 3.40 mg/L, not within the EQS limit with higher organic and inorganic pollutants that is not suitable for fisheries and other aquatic organisms or species.

In the month of December 2020, in Dhanmondi Lake, DO of two water samples varied from 3.80 to 8.90 mg/L, within the EQS limit (>_5 mg/L for fisheries) with lower organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Gulshan-Baridhara Lake, DO of two water samples varied from 2.80 to 2.70 mg/L, not within the EQS limit with higher organic and inorganic pollutants that is not suitable for fisheries and other aquatic organisms or species; in Hatirjheel Lake, DO of two water samples varied from 6.00 to 9.80 mg/L, within the EQS limit with lower organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Ramna Lake, DO of two water samples varied from 6.80 to 10.90 mg/L, within the EQS limit that indicating good quality of water with lower organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Bottola Dia Bari Lake, DO of two water samples varied from 6.90 to 10.20 mg/L, within the EQS limit that indicating good quality of water with lower organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Ashulia urban wetland, DO of two water samples varied from 3.50 to 3.30 mg/L, not within the EQS limit with higher organic and inorganic pollutants that is suitable for fisheries and other aquatic organisms or species; in Birulia urban wetland, DO of two water samples varied from 1.80 to 5.30 mg/L, not within the EQS limit with higher organic and inorganic pollutants that is not suitable for fisheries and other aquatic organisms or species.

From the above values, it was identified that, in Dhanmondi Lake, the lowest DO was recorded in December (3.80 mg/L) at sample location - 01 and not within the EQS limit and the highest was recorded in November (10.0 mg/L) at sample location - 02 and within the EQS limit; in Gulshan-Baridhara Lake, the lowest DO was recorded in November (0.00 mg/L) at sample location - 02 and not within the EQS limit and the highest was recorded in October (6.10 mg/L) at sample location - 01 and within the EQS limit; in Hatirjheel Lake, the lowest DO was recorded in November (0.00 mg/L) at sample location - 02 and not within the EQS limit and the highest was recorded in December (9.80 mg/L) at sample location - 02 and within the EQS limit; in Ramna Lake, the lowest DO was recorded in November (6.70 mg/L) at sample location - 01 and within the EQS limit and the highest was recorded in December (10.90 mg/L) at sample location - 02 and within the EQS limit; in Bottola Dia Bari Lake, the lowest DO was recorded in November (2.60 mg/L) at sample location - 02 and not within the EQS limit and the highest was recorded in December (10.20 mg/L) at sample location - 02 and within the EQS limit; in Ashulia urban wetland, the lowest DO was recorded in December (3.30 mg/L) at sample location - 02 and not within the EQS limit and the highest was recorded in October (7.50 mg/L) at sample location - 01 and within the EQS limit; in Birulia urban wetland, the lowest DO was recorded in December (1.80 mg/L) at sample location - 01 and not within the EQS limit and the highest was recorded in October (8.00 mg/L) at sample location - 01 and within the EQS limit. Following (Figure – 6.5) shows the DO level in study area across three months for sample 1 and 2.

In Dhanmondi Lake, the average DO was recorded 7.03 mg/L which is within the EQS limit (>_5 mg/L for fisheries) and suitable for fisheries; in Gulshan-Baridhara Lake, the average DO was recorded 3.03 mg/L which is not within the EQS limit for fisheries; in Hatirjheel Lake, the average DO was recorded 5.17 mg/L which is within the EQS limit for fisheries; in Ramna Lake, the average DO was recorded 8.22 mg/L which is within the EQS limit for fisheries; in Bottola Dia Bari Lake, the average DO was recorded 6.77 mg/L which is within the EQS limit for fisheries; in Ashulia urban wetland, the average DO was recorded 5.63 mg/L which is within the EQS limit for fisheries; in Birulia urban wetland, the average DO was recorded 5.12 mg/L which is within the EQS limit and suitable for fisheries (Figure – 6.6).

6.1.1.4 Biochemical Oxygen Demand (BOD_5)

In the month of October 2020, in Dhanmondi Lake, Biochemical Oxygen Demand (BOD_5) of two water samples varied from 12.0 to 11.5 mg/L, not within the EQS limit (<_6 mg/L for fisheries) which is not suitable for fisheries and other aquatic organisms or species indicating medium organic matter presence in the water; in Gulshan-Baridhara Lake, BOD_5 of two water samples varied from 29.0 to 30.5 mg/L, not within the EQS limit that indicating significant organic pollution and poor quality of water which is not suitable for fisheries and other aquatic organisms or species indicating higher organic matter presence in the water; in Hatirjheel Lake, BOD_5 of two water samples varied from 46.0 to 43.2 mg/L, not within the EQS limit that indicating significant organic pollution and poor quality of water which is not suitable for fisheries and other aquatic organisms or species indicating higher organic matter presence in the water; in Ramna Lake urban water body, BOD_5 of two water samples varied from 7.00 to 7.80 mg/L, not within the EQS limit which is not suitable for fisheries and other aquatic organisms or species indicating organic matter presence in the water; in Bottola Dia Bari Lake, BOD_5 of two water samples varied from 3.00 to 3.80 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower organic matter presence in the water; in Ashulia urban wetland, BOD_5 of two water samples varied from 6.00 to 7.00 mg/L, nearly or not within the EQS limit which is not suitable for fisheries and other aquatic organisms or species indicating organic matter presence in the water; in Birulia urban wetland, BOD_5 of two water samples varied from 4.00 to 3.80 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower organic matter presence in the water.

In the month of November 2020, in Dhanmondi Lake, BOD_5 of two water samples varied from 13.0 to 6.0 mg/L, not within the EQS limit (<_6 mg/L for fisheries) which is not suitable for fisheries and other aquatic organisms or species indicating organic matter presence in the water; in Gulshan-Baridhara Lake, BOD_5 of two water samples varied from 30.0 to 23.0 mg/L, not within the EQS limit that indicating significant organic pollution and poor quality of water which is not suitable for fisheries and other aquatic organisms or species indicating higher organic matter presence in the water; in Hatirjheel Lake, BOD_5 of two water samples varied from 12.0 to 10.0 mg/L, not within the EQS limit which is not suitable for fisheries and other aquatic organisms or species indicating organic matter presence in the water; in Ramna Lake, BOD_5 of two water samples varied from 12.0 to 3.0 mg/L, not within the EQS limit which is not suitable for fisheries and other aquatic organisms or species indicating organic matter presence in the water; in Bottola Dia Bari Lake, BOD_5 of two water samples varied from 5.0 to 3.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower organic matter presence in the water; in Ashulia urban wetland, BOD_5 of two water samples varied from 12.0 to 5.0 mg/L, not within the EQS limit which is not suitable for fisheries and other aquatic organisms or species indicating organic matter presence in the water; in Birulia urban wetland, BOD_5 of two water samples varied from 13.0 to 3.0 mg/L, not within the EQS limit which is not suitable for fisheries and other aquatic organisms or species indicating organic matter presence in the water.

In the month of December 2020, in Dhanmondi Lake, BOD_5 of two water samples varied from 9.0 to 9.0 mg/L, not within the EQS limit (<_6 mg/L for fisheries) which is not suitable for fisheries and other aquatic organisms or species indicating organic matter presence in the water; in Gulshan-Baridhara Lake, BOD_5 of two water samples varied from 23.0 to 23.0 mg/L, not within the EQS limit that indicating significant organic pollution and poor quality of water which is not suitable for fisheries and other aquatic organisms or species indicating higher organic matter presence in the water; in Hatirjheel Lake, BOD_5 of two water samples varied from 25.0 to 26.0 mg/L, not within the EQS limit that indicating significant organic pollution and poor quality of water which is not suitable for fisheries and other aquatic organisms or species indicating higher organic matter presence in the water; in Ramna Lake, BOD_5 of two water samples varied from 5.0 to 5.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower organic matter presence in the water; in Bottola Dia Bari Lake, BOD_5 of two water samples varied from 14.0 to 14.0 mg/L, not within the EQS limit which is not suitable for fisheries and other aquatic organisms or species indicating organic matter presence in the water; in Ashulia urban wetland, BOD_5 of two water samples varied from 2.0 to 2.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower organic matter presence in the water; in Birulia urban wetland, BOD_5 of two water samples varied from 19.0 to 20.0 mg/L, not within the EQS limit that indicating significant organic pollution and poor quality of water which is not suitable for fisheries and other aquatic organisms or species indicating higher organic matter presence in the water.

From the above values, it was identified that, in Dhanmondi Lake, the lowest BOD_5 was recorded in November (6.0 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in November (13.0 mg/L) at sample location - 01 and not within the EQS limit; in Gulshan-Baridhara Lake, the lowest BOD_5 was recorded in November (23.0 mg/L) at sample location - 02 and December (23.0 mg/L) at sample location - 01 & 02 and not within the EQS limit and the highest was recorded in October (30.50 mg/L) at sample location - 02 and not within the EQS limit; in Hatirjheel Lake, the lowest BOD_5 was recorded in November (10.0 mg/L) at sample location - 02 and not within the EQS limit and the highest was recorded in October (46.0 mg/L) at sample location - 01 and not within the EQS limit; in Ramna Lake, the lowest BOD_5 was recorded in November (3.0 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in November (12.0 mg/L) at sample location - 01 and not within the EQS limit; in Bottola Dia Bari Lake, the lowest BOD_5 was recorded in October and November (3.0 mg/L) at sample location - 01 & 02 and within the EQS limit and the highest was recorded in December (14.0 mg/L) at sample location - 01 & 02 and not within the EQS limit; in Ashulia urban wetland, the lowest BOD_5 was recorded in December (2.0 mg/L) at sample location - 01 & 02 and within the EQS limit and the highest was recorded in November (12.0 mg/L) at sample location - 01 and not within the EQS limit; in Birulia urban wetland, the lowest BOD_5 was recorded in November (3.0 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in December (20.0 mg/L) at sample location - 02 and not within the EQS limit. Following (Figure – 6.7) shows the BOD_5 level in study area across three months for sample 1 and 2.

In Dhanmondi Lake, the average BOD_5 was recorded 10.08 mg/L which is not within the EQS limit (<_6 mg/L for fisheries) and not suitable for fisheries; in Gulshan-Baridhara Lake, the average BOD_5 was recorded 26.42 mg/L which is not within the EQS limit for fisheries; in Hatirjheel Lake, the average BOD_5 was recorded 27.03 mg/L which is not within the EQS limit for fisheries; in Ramna Lake, the average BOD_5 was recorded 6.63 mg/L which is slightly larger than the EQS limit for fisheries; in Bottola Dia Bari Lake, the average BOD_5 was recorded 7.13 mg/L which is not within the EQS limit for fisheries; in Ashulia urban wetland, the average BOD_5 was recorded 5.67 mg/L which is within the EQS limit for fisheries; in Birulia urban wetland, the average BOD_5 was recorded 10.47 mg/L which is not within the EQS limit and not suitable for fisheries (Figure – 6.8).

6.1.1.5 Chemical Oxygen Demand (COD)

In the month of October 2020, in Dhanmondi Lake, Chemical Oxygen Demand (COD) of two water samples varied from 41.0 to 45.0 mg/L, within the EQS limit (200 mg/L) which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Gulshan-Baridhara Lake, COD of two water samples varied from 173.0 to 180.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Hatirjheel Lake, COD of two water samples varied from 151.0 to 158.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating medium inorganic matter presence in the water; in Ramna Lake, COD of two water samples varied from 139.0 to 142.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating medium inorganic matter presence in the water; in Bottola Dia Bari Lake, COD of two water samples varied from 22.0 to 28.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Ashulia urban wetland, COD of two water samples varied from 46.0 to 51.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Birulia urban wetland, COD of two water samples varied from 24.0 to 22.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water.

In the month of November 2020, in Dhanmondi Lake, COD of two water samples varied from 33.0 to 19.0 mg/L, within the EQS limit (200 mg/L) which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Gulshan-Baridhara Lake, COD of two water samples varied from 131.0 to 78.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating medium inorganic matter presence in the water; in Hatirjheel Lake, COD of two water samples varied from 29.0 to 53.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Ramna Lake, COD of two water samples varied from 30.0 to 16.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Bottola Dia Bari Lake, COD of two water samples varied from 28.0 to 11.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Ashulia urban wetland, COD of two water samples varied from 27.0 to 18.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Birulia urban wetland, COD of two water samples varied from 30.0 to 15.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water.

In the month of December 2020, in Dhanmondi Lake, COD of two water samples varied from 44.0 to 17.0 mg/L, within the EQS limit (200 mg/L) which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Gulshan-Baridhara Lake, COD of two water samples varied from 71.0 to 66.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Hatirjheel Lake, COD of two water samples varied from 63.0 to 66.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Ramna Lake, COD of two water samples varied from 29.0 to 32.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Bottola Dia Bari Lake, COD of two water samples varied from 37.0 to 22.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Ashulia urban wetland, COD of two water samples varied from 15.0 to 22.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water; in Birulia urban wetland, COD of two water samples varied from 20.0 to 22.0 mg/L, within the EQS limit which is suitable for fisheries and other aquatic organisms or species indicating lower inorganic matter presence in the water.

From the above values, it was identified that, in Dhanmondi Lake, the lowest COD was recorded in December (17.0 mg/L) at sample location - 02 and within the EQS limit (200 mg/L) and the highest was recorded in October (45.0 mg/L) at sample location - 02 and within the EQS limit (200 mg/L); in Gulshan-Baridhara Lake, the lowest COD was recorded in December (66.0 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in October (180.0 mg/L) at sample location - 02 and within the EQS limit; in Hatirjheel Lake, the lowest COD was recorded in November (29.0 mg/L) at sample location - 01 and within the EQS limit and the highest was recorded in October (158.0 mg/L) at sample location - 02 and within the EQS limit; in Ramna Lake, the lowest COD was recorded in November (16.0 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in October (142.0 mg/L) at sample location - 02 and within the EQS limit; in Bottola Dia Bari Lake, the lowest COD was recorded in November (11.0 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in December (37.0 mg/L) at sample location - 01 and within the EQS limit; in Ashulia urban wetland, the lowest COD was recorded in December (15.0 mg/L) at sample location - 01 and within the EQS limit and the highest was recorded in October (51.0 mg/L) at sample location - 02 and within the EQS limit; in Birulia urban wetland, the lowest COD was recorded in November (15.0 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in November (30.0 mg/L) at sample location - 01 and within the EQS limit. Following (Figure – 6.9) shows the COD level in study area across three months for sample 1 and 2.

In Dhanmondi Lake, the average COD was recorded 33.17 mg/L which is within the EQS limit (200 mg/L) and suitable for fisheries; in Gulshan-Baridhara Lake, the average COD was recorded 116.50 mg/L which is within the EQS limit for fisheries; in Hatirjheel Lake, the average COD was recorded 86.67 mg/L which is within the EQS limit for fisheries; in Ramna Lake, the average COD was recorded 64.67 mg/L which is within the EQS limit for fisheries; in Bottola Dia Bari Lake, the average COD was recorded 24.67 mg/L which is within the EQS limit for fisheries; in Ashulia urban wetland, the average COD was recorded 29.83 mg/L which is within the EQS limit for fisheries; in Birulia urban wetland, the average COD was recorded 22.17 mg/L which is within the EQS limit and suitable for fisheries (Figure – 6.10).

6.1.1.6 Turbidity

In the month of October 2020, in Dhanmondi Lake, Turbidity of two water samples varied from 4.91 to 7.30 NTU, within the EQS limit (10 NTU) which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Gulshan-Baridhara Lake, Turbidity of two water samples varied from 42.2 to 37.5 NTU, not within the EQS limit which indicating higher quantity of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Hatirjheel Lake, Turbidity of two water samples varied from 26.4 to 30.0 NTU, not within the EQS limit which indicating higher quantity of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Ramna Lake, Turbidity of two water samples varied from 5.70 to 10.5 NTU, more or less within the EQS limit which indicating tolerable quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Bottola Dia Bari Lake, Turbidity of two water samples varied from 12.5 to 15.2 NTU, not within the EQS limit which indicating presence of biodegradable organics in runoff which is less suitable for fisheries and other aquatic biodiversity conservation; in Ashulia urban wetland, Turbidity of two water samples varied from 7.28 to 12.0 NTU, within and not within the EQS limit which indicating presence of biodegradable organics in runoff which is less suitable for fisheries and other aquatic biodiversity conservation; in Birulia urban wetland, Turbidity of two water samples varied from 35.2 to 39.3 NTU, not within the EQS limit which indicating higher quantity of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation.

In the month of November 2020, in Dhanmondi Lake, Turbidity of two water samples varied from 25.7 to 32.4 NTU, not within the EQS limit (10 NTU) which indicating higher quantity of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Gulshan-Baridhara Lake, Turbidity of two water samples varied from 45.6 to 48.8 NTU, not within the EQS limit which indicating higher quantity of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Hatirjheel Lake, Turbidity of two water samples varied from 64.2 to 69.0 NTU, not within the EQS limit which indicating higher quantity of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Ramna Lake, Turbidity of two water samples varied from 18.7 to 14.8 NTU, not within the EQS limit which indicating biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Bottola Dia Bari Lake, Turbidity of two water samples varied from 41.0 to 62.0 NTU, not within the EQS limit which indicating higher quantity of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Ashulia urban wetland, Turbidity of two water samples varied from 60.5 to 63.2 NTU, not within the EQS limit which indicating higher quantity of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Birulia urban wetland, Turbidity of two water samples varied from 37.4 to 33.2 NTU, not within the EQS limit which indicating higher quantity of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation.

In the month of December 2020, in Dhanmondi Lake, Turbidity of two water samples varied from 8.91 to 5.21 NTU, within the EQS limit (10 NTU) which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Gulshan-Baridhara Lake, Turbidity of two water samples varied from 32.6 to

40.1 NTU, not within the EQS limit which indicating higher quantities of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Hatirjheel Lake, Turbidity of two water samples varied from 28.4 to 26.6 NTU, not within the EQS limit which indicating higher quantities of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Ramna Lake, Turbidity of two water samples varied from 18.6 to 18.2 NTU, not within the EQS limit which indicating higher quantities of biodegradable organics in runoff which is less suitable for fisheries and other aquatic biodiversity conservation; in Bottola Dia Bari Lake, Turbidity of two water samples varied from 58.6 to 56.0 NTU, not within the EQS limit which indicating higher quantities of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Ashulia urban wetland, Turbidity of two water samples varied from 62.0 to 60.8 NTU, not within the EQS limit which indicating higher quantities of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Birulia urban wetland, Turbidity of two water samples varied from 58.3 to 58.6 NTU, not within the EQS limit which indicating higher quantities of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation.

From the above values, it was identified that, in Dhanmondi Lake, the lowest Turbidity was recorded in October (4.91 NTU) at sample location - 01 and within the EQS limit (10 NTU) and the highest was recorded in November (32.40 NTU) at sample location - 02 and not within the EQS limit; in Gulshan-Baridhara Lake, the lowest Turbidity was recorded in December (32.60 NTU) at sample location - 01 and not within the EQS limit and the highest was recorded in November (48.80 NTU) at sample location - 02 and not within the EQS limit; in Hatirjheel Lake, the lowest Turbidity was recorded in October (26.40 NTU) at sample location - 01 and not within the EQS limit and the highest was recorded in November (69.0 NTU) at sample location - 02 and not within the EQS limit; in Ramna Lake, the lowest Turbidity was recorded in October (5.70 NTU) at sample location - 01 and within the EQS limit and the highest was recorded in November (18.70 NTU) at sample location - 01 and not within the EQS limit; in Bottola Dia Bari Lake, the lowest Turbidity was recorded in October (12.50 NTU) at sample location - 01 and not within the EQS limit and the highest was recorded in November (62.0 NTU) at sample location - 02 and not within the EQS limit; in Ashulia urban wetland, the lowest Turbidity was recorded in October (7.28 NTU) at sample location - 01 and within the EQS limit and the highest was recorded in November (63.20 NTU) at sample location - 02 and not within the EQS limit; in Birulia urban wetland, the lowest Turbidity was recorded in November (33.2 NTU) at sample location - 02 and not within the EQS limit and the highest was recorded in December (58.60 NTU) at sample location - 02 and not within the EQS limit. Following (Figure – 6.11) shows the Turbidity level in study area across three months for sample 1 and 2.

In Dhanmondi Lake, the average Turbidity was recorded 14.07 NTU which is not within the EQS limit (10 NTU) and not suitable for fisheries; in Gulshan-Baridhara Lake, the average Turbidity was recorded 41.13 NTU which is not within the EQS limit for fisheries; in Hatirjheel Lake, the average Turbidity was recorded 40.77 NTU which is not within the EQS limit for fisheries; in Ramna Lake, the average Turbidity was recorded 14.42 NTU which is not within the EQS limit for fisheries; in Bottola Dia Bari Lake, the average Turbidity was recorded 40.88 NTU which is not within the EQS limit for fisheries; in Ashulia urban wetland, the average Turbidity was recorded 44.30 NTU which is not within the EQS limit for fisheries; in Birulia urban wetland, the average Turbidity was recorded 43.67 NTU which is not within the EQS limit and not suitable for fisheries (Figure – 6.12).

6.1.1.7 Nitrate-Nitrogen (NO_3-N)

In the month of October 2020, in Dhanmondi Lake, Nitrate-Nitrogen (NO_3-N) of two water samples varied from 0.40 to 0.30 mg/L, within the EQS limit (10 mg/L) which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Gulshan-Baridhara Lake, NO_3-N of two water samples varied from 1.40 to 1.40 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Hatirjheel Lake, NO_3-N of two water samples varied from 1.50 to 1.40 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ramna Lake, NO_3-N of two water samples varied from 0.80 to 0.70 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Bottola Dia Bari Lake, NO_3-N of two water samples varied from 0.40 to 0.30 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ashulia urban wetland, NO_3-N of two water samples varied from 1.00 to 0.80 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Birulia urban wetland, NO_3-N of two water samples varied from 0.80 to 0.90 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation.

In the month of November 2020, in Dhanmondi Lake, NO_3-N of two water samples varied from 0.80 to 0.70 mg/L, within the EQS limit (10 mg/L) which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Gulshan-Baridhara Lake, NO_3-N of two water samples varied from 1.40 to 1.10 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Hatirjheel Lake, NO_3-N of two water samples varied from 0.70 to 1.00 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ramna Lake, NO_3-N of two water samples varied from 0.60 to 1.00 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Bottola Dia Bari Lake, NO_3-N of two water samples varied from 1.00 to 1.20 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ashulia urban wetland, NO_3-N of two water samples varied from 0.40 to 0.20 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Birulia urban wetland, NO_3-N of two water samples varied from 0.40 to 0.70 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation.

In the month of December 2020, in Dhanmondi Lake, NO_3-N of two water samples varied from 1.00 to 1.20 mg/L, within the EQS limit (10 mg/L) which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Gulshan-Baridhara Lake, NO_3-N of two water samples varied from 1.70 to 1.00 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Hatirjheel

Lake, NO_3-N of two water samples varied from 0.90 to 1.10 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ramna Lake, NO_3-N of two water samples varied from 0.80 to 1.00 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Bottola Dia Bari Lake, NO_3-N of two water samples varied from 1.40 to 0.80 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ashulia urban wetland, NO_3-N of two water samples varied from 0.80 to 0.60 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Birulia urban wetland, NO_3-N of two water samples varied from 1.70 to 1.40 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation.

From the above values, it was identified that, in Dhanmondi Lake, the lowest NO_3-N was recorded in October (0.30 mg/L) at sample location - 02 and within the EQS limit (10 mg/L) and the highest was recorded in December (1.20 mg/L) at sample location - 02 and within the EQS limit; in Gulshan-Baridhara Lake, the lowest NO_3-N was recorded in December (1.00 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in December (1.70 mg/L) at sample location - 01 and within the EQS limit; in Hatirjheel Lake, the lowest NO_3-N was recorded in November (0.70 mg/L) at sample location - 01 and within the EQS limit and the highest was recorded in October (1.50 mg/L) at sample location - 01 and within the EQS limit; in Ramna Lake, the lowest NO_3-N was recorded in November (0.60 mg/L) at sample location - 01 and within the EQS limit and the highest was recorded in November and December (1.00 mg/L) at sample location - 02 and within the EQS limit; in Bottola Dia Bari Lake, the lowest NO_3-N was recorded in October (0.30 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in December (1.40 mg/L) at sample location - 01 and within the EQS limit; in Ashulia urban wetland, the lowest NO_3-N was recorded in November (0.20 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in October (1.00 mg/L) at sample location - 01 and within the EQS limit; in Birulia urban wetland, the lowest NO_3-N was recorded in November (0.40 mg/L) at sample location - 01 and within the EQS limit and the highest was recorded in December (1.70 mg/L) at sample location - 01 and within the EQS limit. Following (Figure – 6.13) shows the NO_3-N level in study area across three months for sample 1 and 2.

In Dhanmondi Lake, the average NO_3-N was recorded 0.73 mg/L which is within the EQS limit (10 mg/L) and suitable for fisheries; in Gulshan-Baridhara Lake, the average NO_3-N was recorded 1.33 mg/L which is within the EQS limit for fisheries; in Hatirjheel Lake, the average NO_3-N was recorded 1.10 mg/L which is within the EQS limit for fisheries; in Ramna Lake, the average NO_3-N was recorded 0.82 mg/L which is within the EQS limit for fisheries; in Bottola Dia Bari Lake, the average NO_3-N was recorded 0.85 mg/L which is within the EQS limit for fisheries; in Ashulia urban wetland, the average NO_3-N was recorded 0.63 mg/L which is within the EQS limit for fisheries; in Birulia urban wetland, the average NO_3-N was recorded 0.98 mg/L which is within the EQS limit and suitable for fisheries (Figure – 6.14).

6.1.1.8 Phosphate (PO_4)

In the month of October 2020, in Dhanmondi Lake, Phosphate (PO_4) of two water samples varied from 5.10 to 4.80 mg/L, within the EQS limit (6 mg/L) which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Gulshan-Baridhara Lake, PO_4 of two water samples varied from 8.40 to 8.70 mg/L, not within the EQS limit which indicating higher quantity of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Hatirjheel Lake, PO_4 of two water samples varied from 18.1 to 17.5 mg/L, not within the EQS limit which indicating higher quantity of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Ramna Lake, PO_4 of two water samples varied from 0.10 to 0.10 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Bottola Dia Bari Lake, PO_4 of two water samples varied from 7.60 to 6.80 mg/L, not within the EQS limit which indicating comparatively higher quantity of biodegradable organics in runoff which is less suitable for fisheries and other aquatic biodiversity conservation; in Ashulia urban wetland, PO_4 of two water samples varied from 0.70 to 0.50 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Birulia urban wetland, PO_4 of two water samples varied from 3.40 to 3.80 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation.

In the month of November 2020, in Dhanmondi Lake, PO_4 of two water samples varied from 1.50 to 1.20 mg/L, within the EQS limit (6 mg/L) which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Gulshan-Baridhara Lake, PO_4 of two water samples varied from 0.90 to 0.70 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Hatirjheel Lake, PO_4 of two water samples varied from 13.4 to 15.2 mg/L, not within the EQS limit which indicating higher quantity of biodegradable organics in runoff which is not suitable for fisheries and other aquatic biodiversity conservation; in Ramna Lake, PO_4 of two water samples varied from 0.80 to 0.70 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Bottola Dia Bari Lake, PO_4 of two water samples varied from 3.00 to 3.20 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ashulia urban wetland, PO_4 of two water samples varied from 0.00 to 0.20 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Birulia urban wetland, PO_4 of two water samples varied from 0.30 to 0.50 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation.

In the month of December 2020, in Dhanmondi Lake, PO_4 of two water samples varied from 4.90 to 5.00 mg/L, within the EQS limit (6 mg/L) which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Gulshan-Baridhara Lake, PO_4 of two water samples varied from 4.40 to 4.30 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Hatirjheel Lake, PO_4 of two water samples varied from 8.00 to 8.80 mg/L, not within the EQS limit which indicating higher quantity of biodegradable organics in runoff which is less suitable for fisheries and other aquatic biodiversity conservation; in Ramna Lake, PO_4 of two water samples varied from 4.80 to 4.90 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Bottola Dia Bari Lake, PO_4 of two water samples varied from 6.00 to 6.20 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ashulia urban wetland, PO_4 of two water samples varied from 4.20 to 5.70 mg/L, within the EQS limit which indicating less quantity of biodegradable organics in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Birulia urban wetland, PO_4 of two water samples varied from 6.30 to 6.50 mg/L, slightly crossed the EQS limit which indicating higher quantity of biodegradable organics in runoff which is less suitable for fisheries and other aquatic biodiversity conservation.

From the above values, it was identified that, in Dhanmondi Lake, the lowest PO_4 was recorded in November (1.20 mg/L) at sample location - 02 and within the EQS limit (6 mg/L) and the highest was recorded in October (5.10 mg/L) at sample location - 01 and within the EQS limit; in Gulshan-Baridhara Lake, the lowest PO_4 was recorded in November (0.70 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in October (8.70 mg/L) at sample location - 02 and not within the EQS limit; in Hatirjheel Lake, the lowest PO_4 was recorded in December (8.00 mg/L) at sample location - 01 and not within the EQS limit and the highest was recorded in October (18.10 mg/L) at sample location - 01 and not within the EQS limit; in Ramna Lake, the lowest PO_4 was recorded in October (0.10 mg/L) at sample location - 01 & 02 and within the EQS limit and the highest was recorded in December (4.90 mg/L) at sample location - 02 and within the EQS limit; in Bottola Dia Bari Lake, the lowest PO_4 was recorded in November (3.00 mg/L) at sample location - 01 and within the EQS limit and the highest was recorded in October (7.60 mg/L) at sample location - 01 and not within the EQS limit; in Ashulia urban wetland, the lowest PO_4 was recorded in November (0.00 mg/L) at sample location - 01 and within the EQS limit and the highest was recorded in December (5.70 mg/L) at sample location - 02 and within the EQS limit; in Birulia urban wetland, the lowest PO_4 was recorded in November (0.30 mg/L) at sample location - 01 and within the EQS limit and the highest was recorded in December (6.50 mg/L) at sample location - 02 and not within the EQS limit. Following (Figure – 6.15) shows the PO_4 level in study area across three months for sample 1 and 2.

In Dhanmondi Lake, the average PO_4 was recorded 3.75 mg/L which is within the EQS limit (6 mg/L) and suitable for fisheries; in Gulshan-Baridhara Lake, the average PO_4 was recorded 4.57 mg/L which is within the EQS limit for fisheries; in Hatirjheel Lake, the average PO_4 was recorded 13.50 mg/L which is not within the EQS limit for fisheries; in Ramna Lake, the average PO_4 was recorded 1.90 mg/L which is within the EQS limit for fisheries; in Bottola Dia Bari Lake, the average PO_4 was recorded 5.47 mg/L which is within the EQS limit for fisheries; in Ashulia urban wetland, the average PO_4 was recorded 1.88 mg/L which is within the EQS limit for fisheries; in Birulia urban wetland, the average PO_4 was recorded 3.47 mg/L which is within the EQS limit and suitable for fisheries (Figure – 6.16).

6.1.1.9 Total Dissolved Solid (TDS)

In the month of October 2020, in Dhanmondi Lake, Total Dissolved Solid (TDS) of two water samples varied from 149.5 to 145.3 mg/L, within the EQS limit (2100 mg/L) which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Gulshan-Baridhara Lake, TDS of two water samples varied from 196.1 to 186.2 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Hatirjheel Lake, TDS of two water samples varied from 251.0 to 246.0 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ramna Lake, TDS of two water samples varied from 73.0 to 79.0 mg/L, within the EQS limit which indicating much less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Bottola Dia Bari Lake, TDS of two water samples varied from 150.0 to 148.0 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ashulia urban wetland, TDS of two water samples varied from 71.0 to 76.0 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Birulia urban wetland, TDS of two water samples varied from 70.0 to 68.0 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation.

In the month of November 2020, in Dhanmondi Lake, TDS of two water samples varied from 137.7 to 137.3 mg/L, within the EQS limit (2100 mg/L) which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Gulshan-Baridhara Lake, TDS of two water samples varied from 213.0 to 212.2 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Hatirjheel Lake, TDS of two water samples varied from 220.0 to 213.0 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ramna Lake, TDS of two water samples varied from 78.70 to 78.10 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Bottola Dia Bari Lake, TDS of two water samples varied from 152.3 to 154.2 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ashulia urban wetland, TDS of two water samples varied from 80.60 to 82.80 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Birulia urban wetland, TDS of two water samples varied from 81.0 to 83.20 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation.

In the month of December 2020, in Dhanmondi Lake, TDS of two water samples varied from 125.0 to 127.0 mg/L, within the EQS limit (2100 mg/L) which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Gulshan-Baridhara Lake, TDS of two water samples varied from 259.0 to 253.0 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Hatirjheel Lake, TDS of two water samples varied from 273.0 to 273.0 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ramna Lake, TDS of two water samples varied from 76.0 to 75.0 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Bottola Dia Bari Lake, TDS of two water samples varied from 161.0 to 163.0 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Ashulia urban wetland, TDS of two water samples varied from 320.0 to 318.0 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation; in Birulia urban wetland, TDS of two water samples varied from 265.0 to 268.0 mg/L, within the EQS limit which indicating less quantity of dissolved solid in runoff which is suitable for fisheries and other aquatic biodiversity conservation.

From the above values, it was identified that, in Dhanmondi Lake, the lowest TDS was recorded in December (125.0 mg/L) at sample location - 01 and within the EQS limit (2100 mg/L) and the highest was recorded in October (149.5 mg/L) at sample location - 01 and within the EQS limit; in Gulshan-Baridhara Lake, the lowest TDS was recorded in October (186.2 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in December (259.0 mg/L) at sample location - 01 and within the EQS limit; in Hatirjheel Lake, the lowest TDS was recorded in November (213.0 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in December (273.0 mg/L) at sample location - 01 & 02 and within the EQS limit; in Ramna Lake, the lowest TDS was recorded in October (73.0 mg/L) at sample location - 01 and within the EQS limit and the highest was recorded in October (79.0 mg/L) at sample location - 02 and within the EQS limit; in Bottola Dia Bari Lake, the lowest TDS was recorded in October (148.0 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in December (163.0 mg/L) at sample location - 02 and within the EQS limit; in Ashulia urban wetland, the lowest TDS was recorded in October (71.0 mg/L) at sample location - 01 and within the EQS limit and the highest was recorded in December (320.0 mg/L) at sample location - 01 and within the EQS limit; in Birulia urban wetland, the lowest TDS was recorded in October (68.0 mg/L) at sample location - 02 and within the EQS limit and the highest was recorded in December (268.0 mg/L) at sample location - 02 and within the EQS limit. Following (Figure – 6.17) shows the TDS level in study area across three months for sample 1 and 2.

In Dhanmondi Lake, the average TDS was recorded 136.97 mg/L which is within the EQS limit (2100 mg/L) and suitable for fisheries; in Gulshan-Baridhara Lake, the average TDS was recorded 219.92 mg/L which is within the EQS limit for fisheries; in Hatirjheel Lake, the average TDS was recorded 246.0 mg/L which is within the EQS limit for fisheries; in Ramna Lake, the average TDS was recorded 76.63 mg/L which is within the EQS limit for fisheries; in Bottola Dia Bari Lake, the average TDS was recorded 154.75 mg/L which is within the EQS limit for fisheries; in Ashulia urban wetland, the average TDS was recorded 158.07 mg/L which is within the EQS limit for fisheries; in Birulia urban wetland, the average TDS was recorded 139.20 mg/L which is within the EQS limit and suitable for fisheries (Figure – 6.18).

6.1.1.10 Electrical Conductivity (EC)

In the month of October 2020, in Dhanmondi Lake, Electrical Conductivity (EC) of two water samples varied from 279.0 to 283.0 umohos/cm, within the EQS limit (1200 umohos/cm); in Gulshan-Baridhara Lake, EC of two water samples varied from 363.0 to 359.0 umohos/cm, within the EQS limit; in Hatirjheel Lake, EC of two water samples varied from 463.0 to 467.0 umohos/cm, within the EQS limit; in Ramna Lake, EC of two water samples varied from 137.0 to 142.0 umohos/cm, within the EQS limit; in Bottola Dia Bari Lake, EC of two water samples varied from 280.0 to 287.0 umohos/cm, within the EQS limit; in Ashulia urban wetland, EC of two water samples varied from 132.0 to 128.0 umohos/cm, within the EQS limit; in Birulia urban wetland, EC of two water samples varied from 132.0 to 129.0 umohos/cm, within the EQS limit.

In the month of November 2020, in Dhanmondi Lake, EC of two water samples varied from 279.0 to 277.0 umohos/cm, within the EQS limit (1200 umohos/cm); in Gulshan-Baridhara Lake, EC of two water samples varied from 427.0 to 427.3 umohos/cm, within the EQS limit; in Hatirjheel Lake, EC of two water samples varied from 450.0 to 447.0 umohos/cm, within the EQS limit; in Ramna Lake, EC of two water samples varied from 157.7 to 159.1 umohos/cm, within the EQS limit; in Bottola Dia Bari Lake, EC of two water samples varied from 304.0 to 311.0 umohos/cm, within the EQS limit; in Ashulia urban wetland, EC of two water samples varied from 165.0 to 167.8 umohos/cm, within the EQS limit; in Birulia urban wetland, EC of two water samples varied from 167.5 to 169.1 umohos/cm, within the EQS limit.

In the month of December 2020, in Dhanmondi Lake, EC of two water samples varied from 233.0 to 233.0 umohos/cm, within the EQS limit (1200 umohos/cm); in Gulshan-Baridhara Lake, EC of two water samples varied from 462.0 to 461.0 umohos/cm, within the EQS limit; in Hatirjheel Lake, EC of two water samples varied from 476.0 to 476.0 umohos/cm, within the EQS limit; in Ramna Lake, EC of two water samples varied from 144.0 to 144.0 umohos/cm, within the EQS limit; in Bottola Dia Bari Lake, EC of two water samples varied from 295.0 to 295.0 umohos/cm, within the EQS limit; in Ashulia urban wetland, EC of two water samples varied from 565.0 to 566.0 umohos/cm, within the EQS limit; in Birulia urban wetland, EC of two water samples varied from 472.0 to 471.0 umohos/cm, within the EQS limit.

From the above values, it was identified that, in Dhanmondi Lake, the lowest EC was recorded in December (233.0 umohos/cm) at sample location - 01 & 02 and within the EQS limit (1200 umohos/cm) and the highest was recorded in October (283.0 umohos/cm) at sample location - 02 and within the EQS limit; in Gulshan-Baridhara Lake, the lowest EC was recorded in October (359.0 umohos/cm) at sample location - 02 and within the EQS limit and the highest was recorded in December (462.0 umohos/cm) at sample location - 01 and within the EQS limit; in Hatirjheel Lake, the lowest EC was recorded in November (447.0 umohos/cm) at sample location - 02 and within the EQS limit and the highest was recorded in December (476.0 umohos/cm) at sample location - 01 & 02 and within the EQS limit; in Ramna Lake, the lowest EC was recorded in October (137.0 umohos/cm) at sample location - 01 and within the EQS limit and the highest was recorded in November (159.1 umohos/cm) at sample location - 02 and within the EQS limit; in Bottola Dia Bari Lake, the lowest EC was recorded in October (280.0 umohos/cm) at sample location - 01 and within the EQS limit and the highest was recorded in November (311.0 umohos/cm) at sample location - 02 and within the EQS limit; in Ashulia urban wetland, the lowest EC was recorded in October

(128.0 umohos/cm) at sample location - 02 and within the EQS limit and the highest was recorded in December (566.0 umohos/cm) at sample location - 02 and within the EQS limit; in Birulia urban wetland, the lowest EC was recorded in October (129.0 umohos/cm) at sample location - 02 and within the EQS limit and the highest was recorded in December (472.0 umohos/cm) at sample location - 01 and within the EQS limit. Following (Figure – 6.19) shows the EC level in study area across three months for sample 1 and 2.

In Dhanmondi Lake, the average EC was recorded 264.0 umohos/cm which is within the EQS limit (1200 umohos/cm) and suitable for fisheries; in Gulshan-Baridhara Lake, the average EC was recorded 416.55 umohos/cm which is within the EQS limit for fisheries; in Hatirjheel Lake, the average EC was recorded 463.17 umohos/cm which is within the EQS limit for fisheries; in Ramna Lake, the average EC was recorded 147.30 umohos/cm which is within the EQS limit for fisheries; in Bottola Dia Bari Lake, the average EC was recorded 295.33 umohos/cm which is within the EQS limit for fisheries; in Ashulia urban wetland, the average EC was recorded 287.30 umohos/cm which is within the EQS limit for fisheries; in Birulia urban wetland, the average EC was recorded 256.77 umohos/cm which is within the EQS limit and suitable for fisheries (Figure – 6.20).

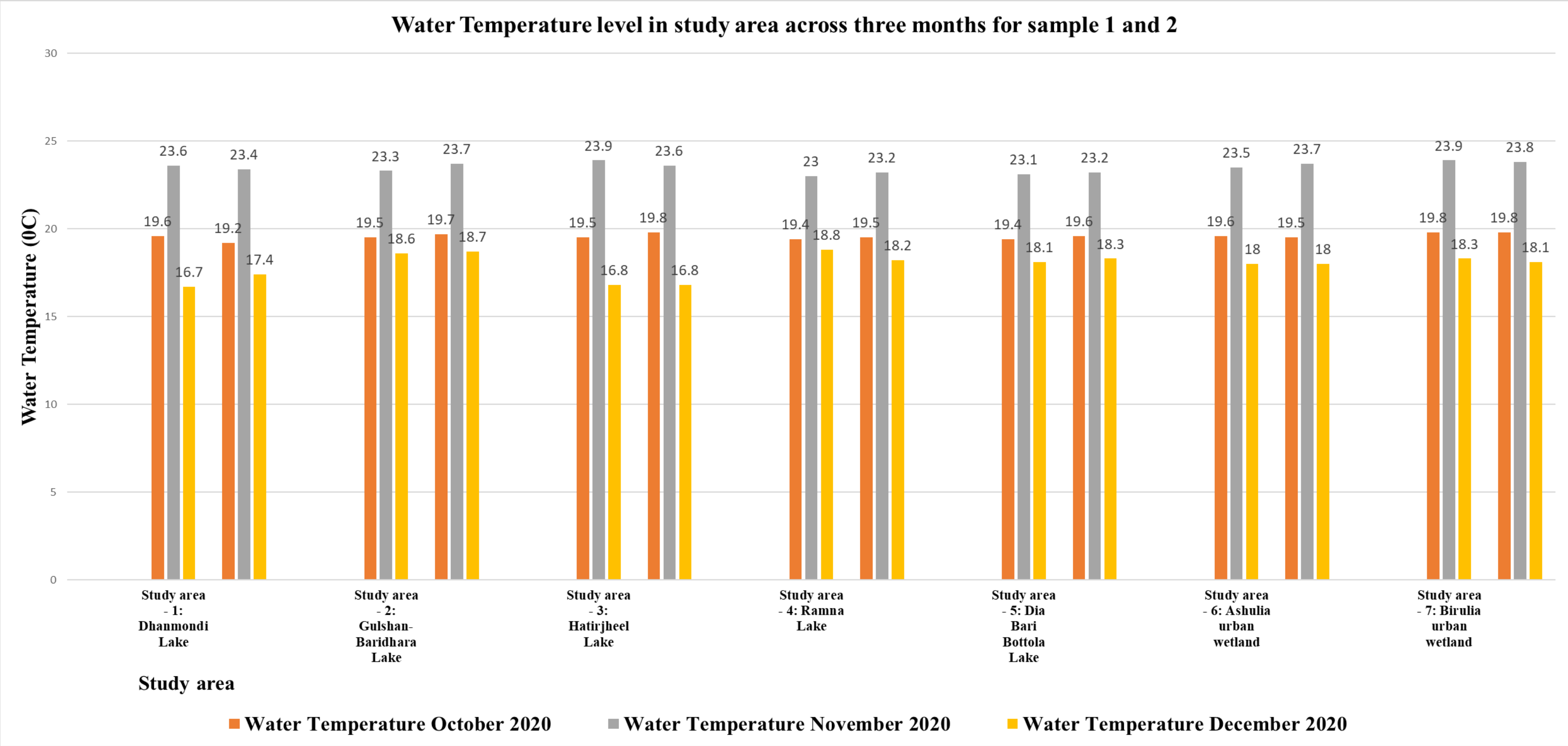


Figure – 6.1: Water Temperature level in study area across three months for sample 1 and 2

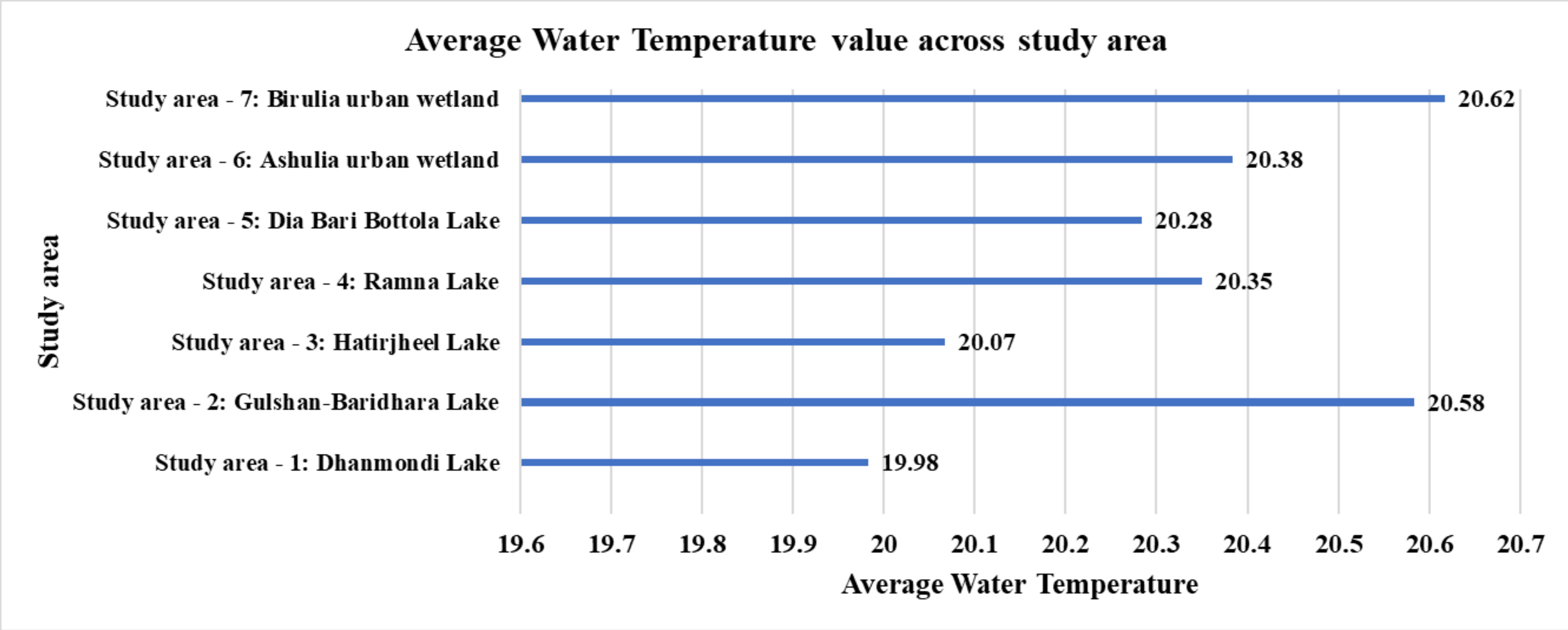


Figure – 6.2: Average Water Temperature value across study area

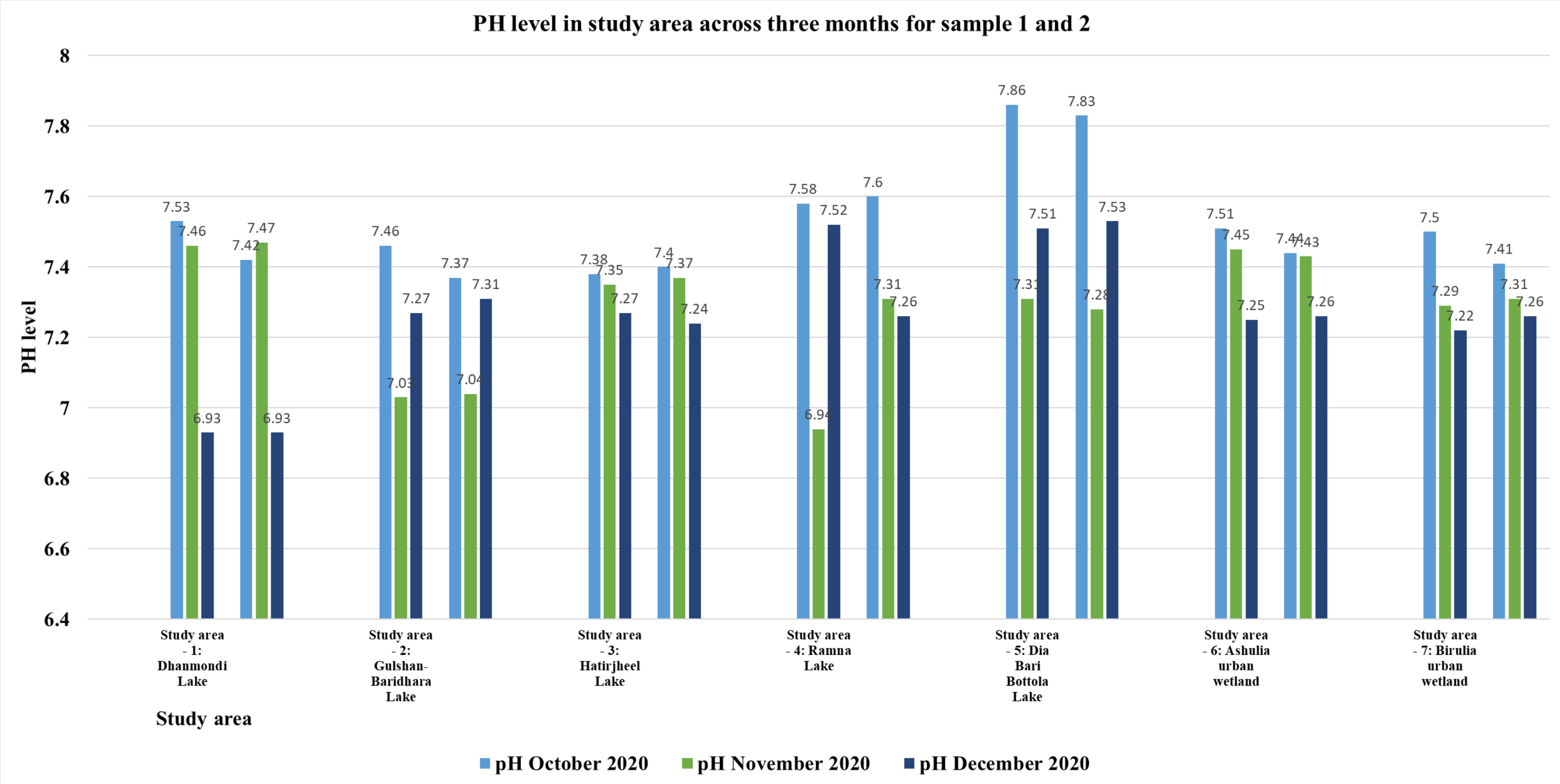


Figure – 6.3: PH level in study area across three months for sample 1 and 2

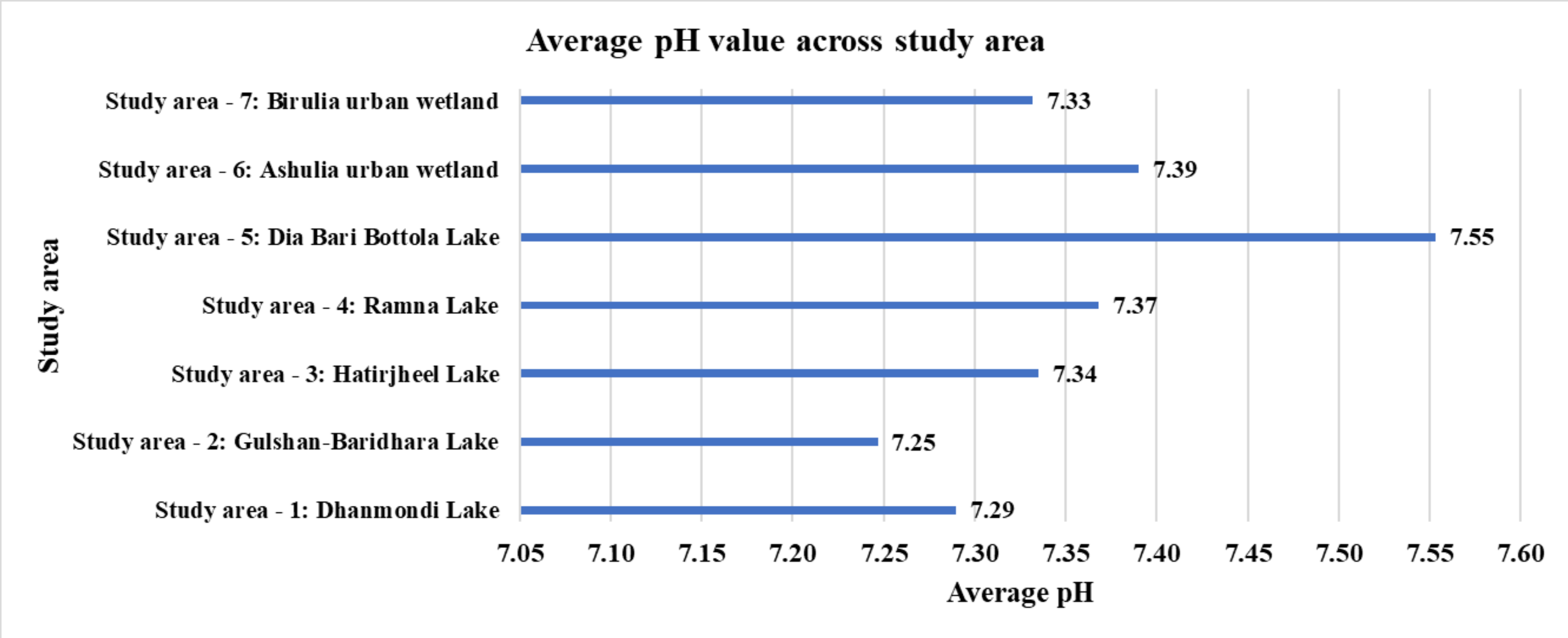


Figure – 6.4: Average PH value across study area

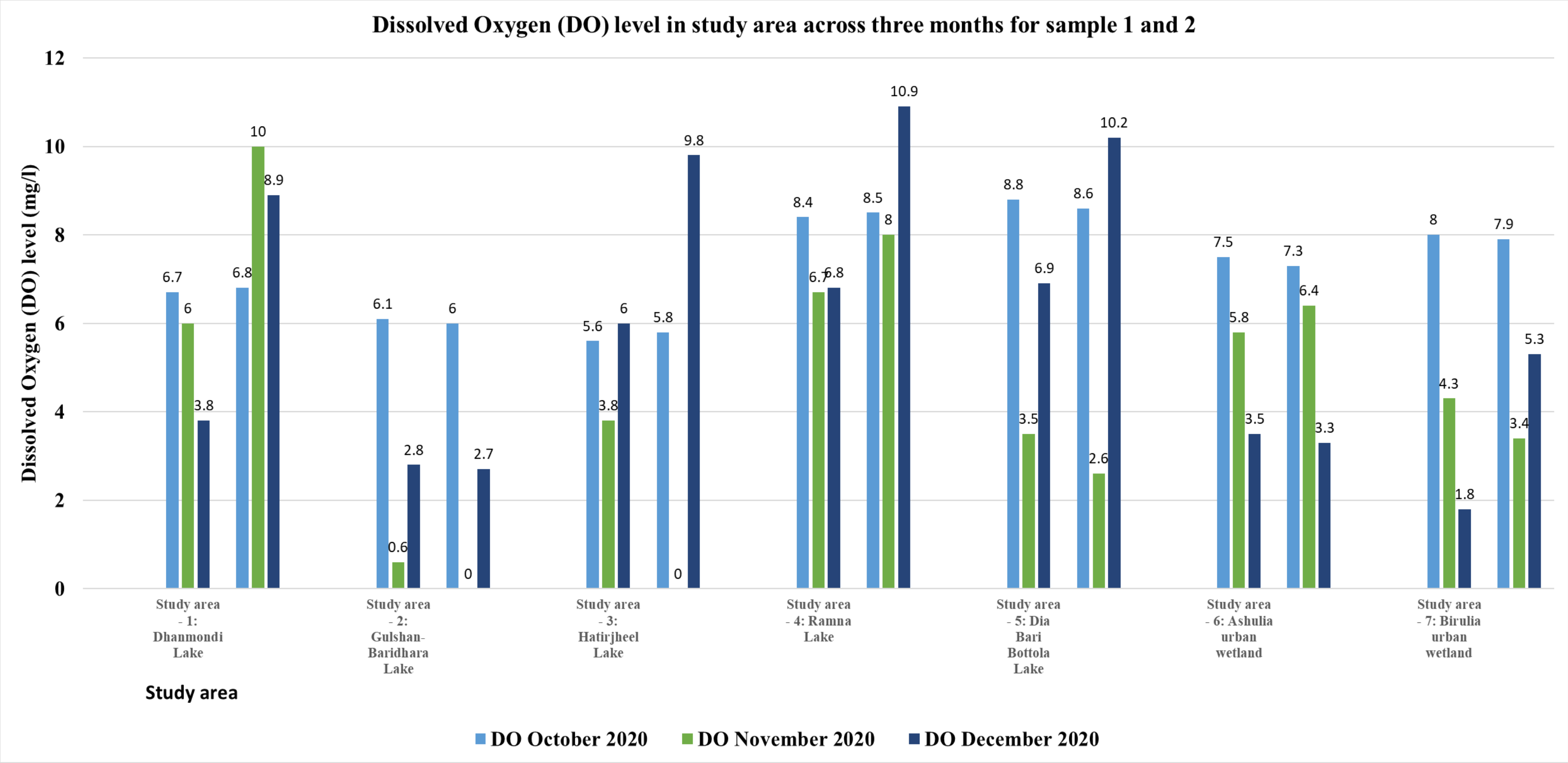


Figure – 6.5: Dissolved Oxygen (DO) level in study area across three months for sample 1 and 2

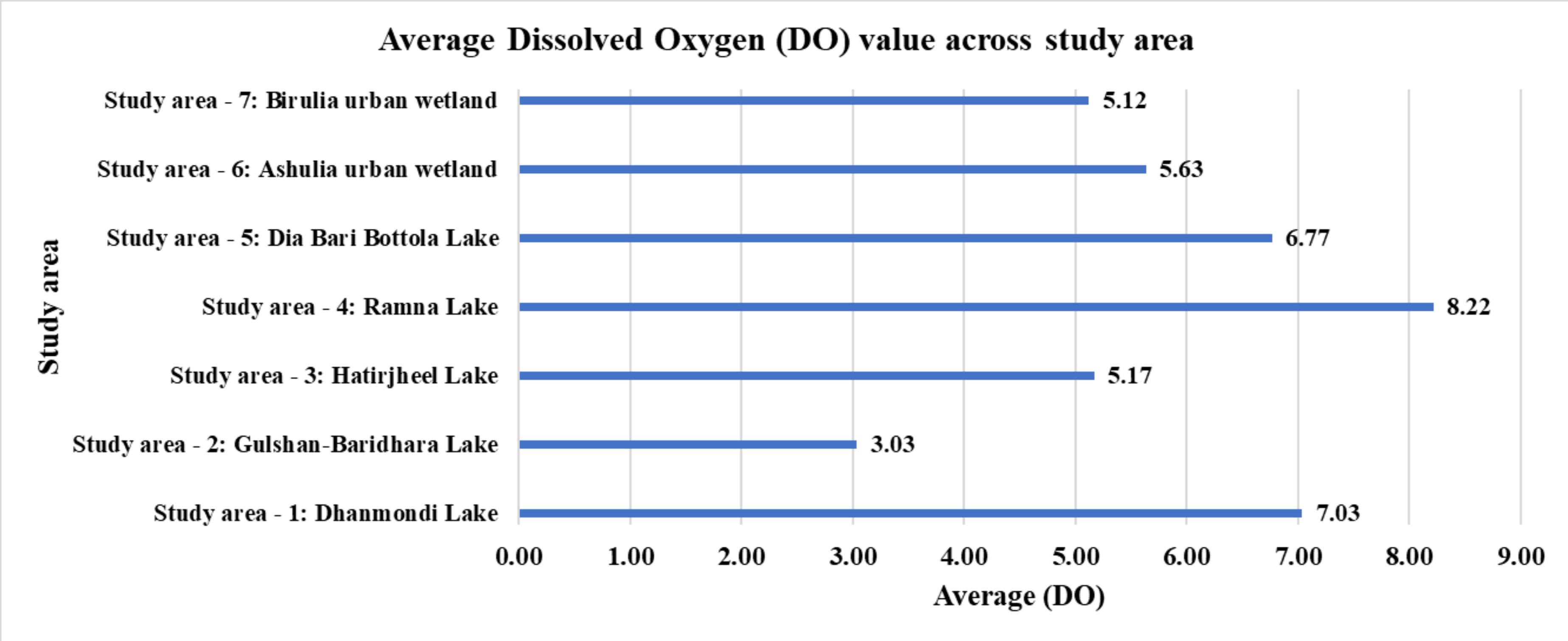


Figure – 6.6: Average DO value across study area

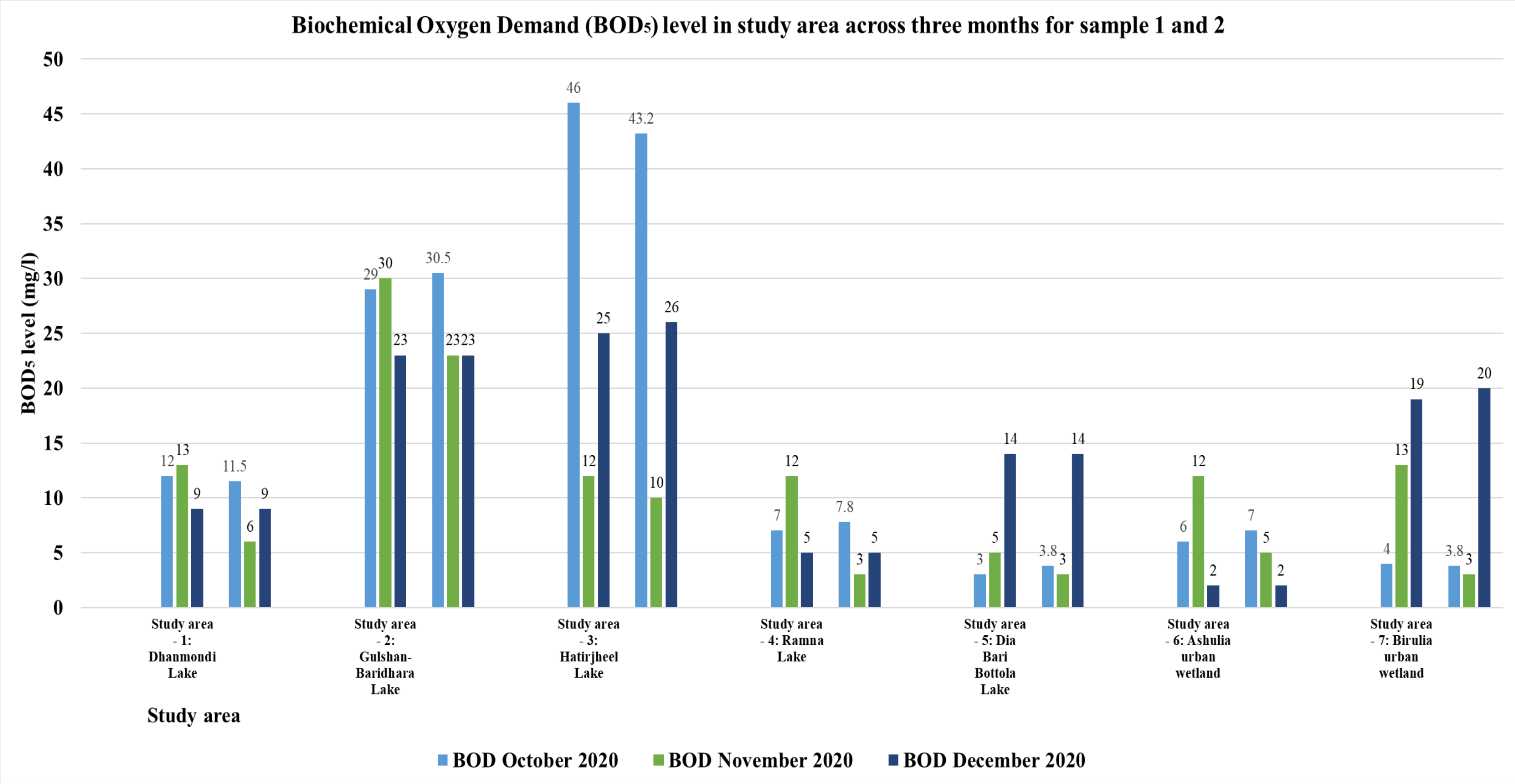


Figure – 6.7: Biochemical Oxygen Demand (BOD5) level in study area across three months for sample 1 and 2

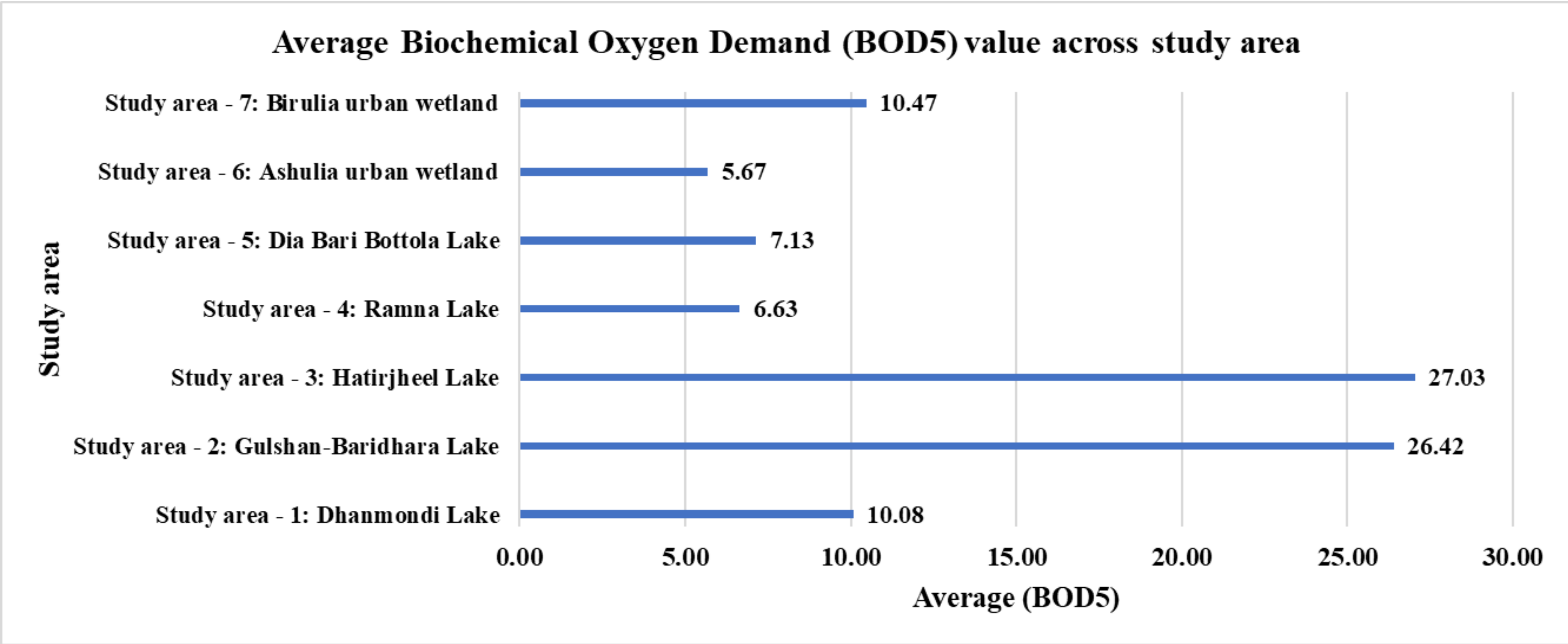


Figure – 6.8: Average BOD5 value across study area

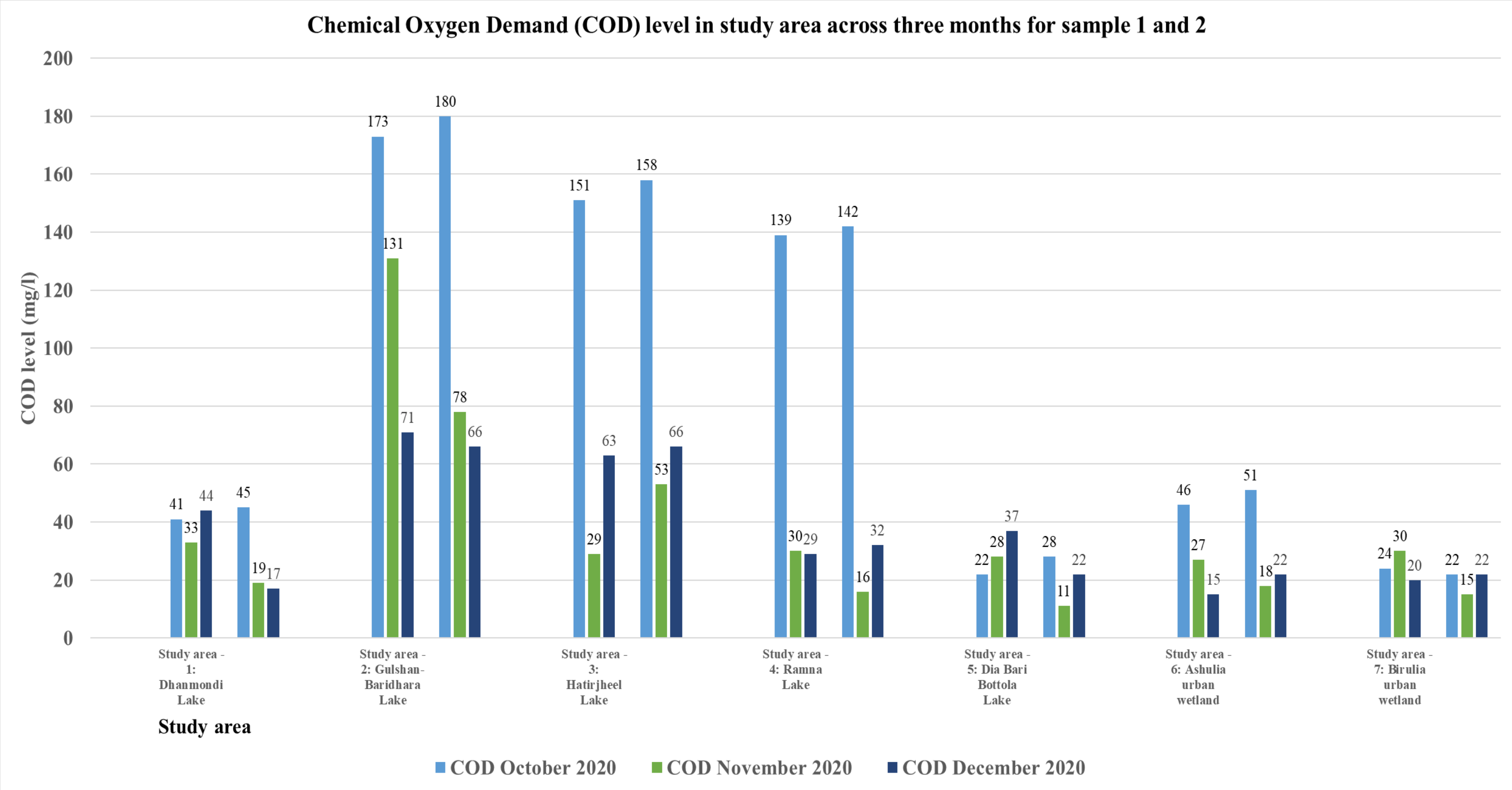


Figure – 6.9: Chemical Oxygen Demand (COD) level in study area across three months for sample 1 and 2

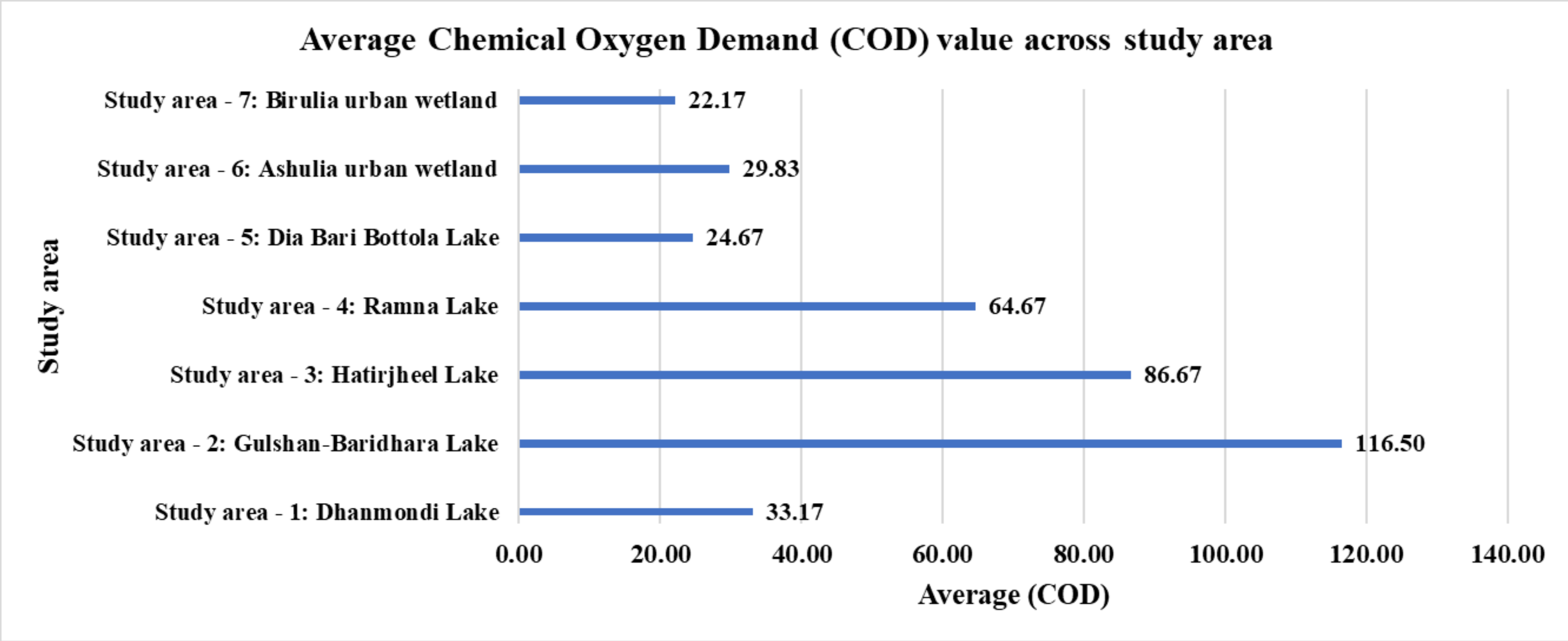


Figure – 6.10: Average COD value across study area

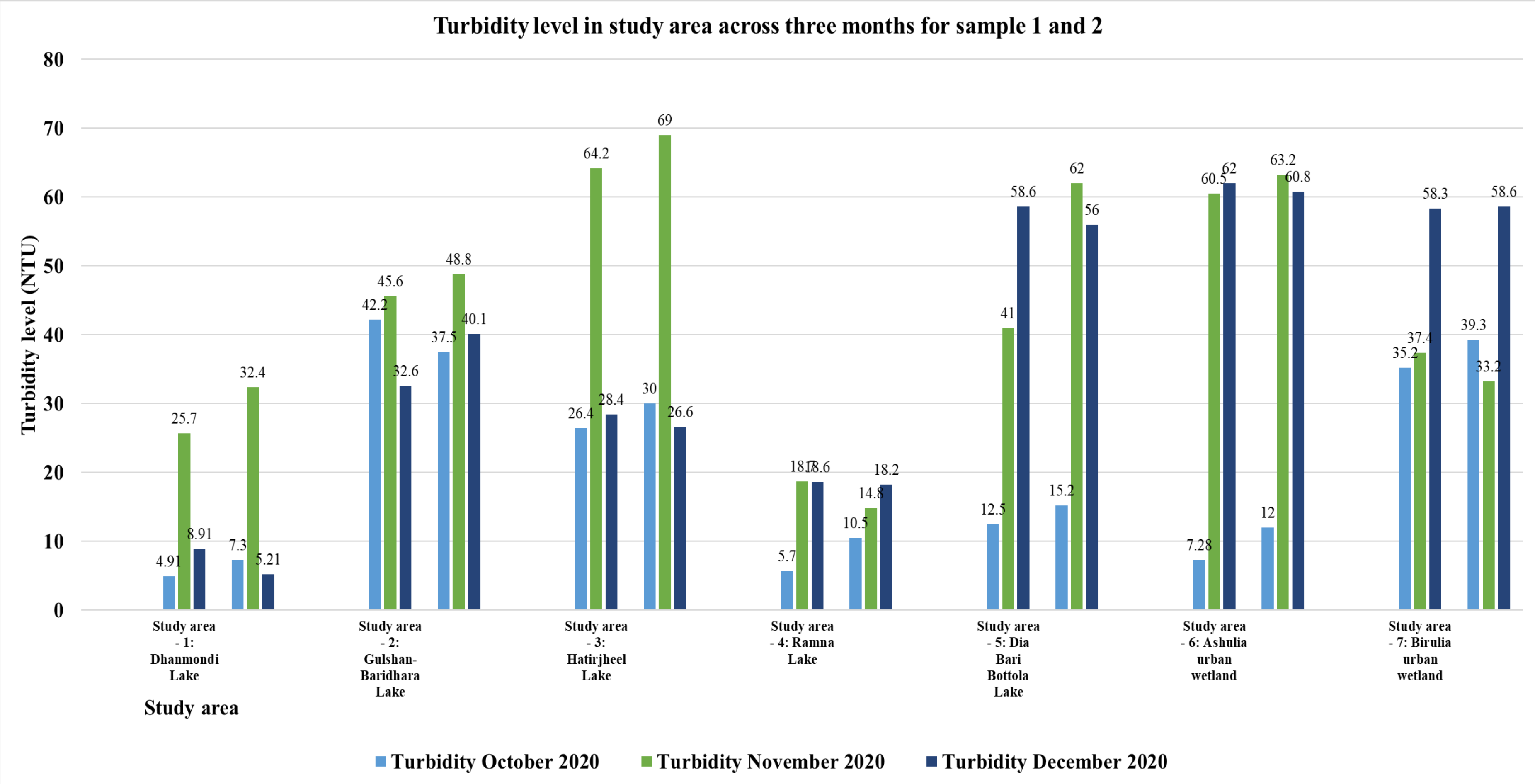


Figure – 6.11: Turbidity level in study area across three months for sample 1 and 2

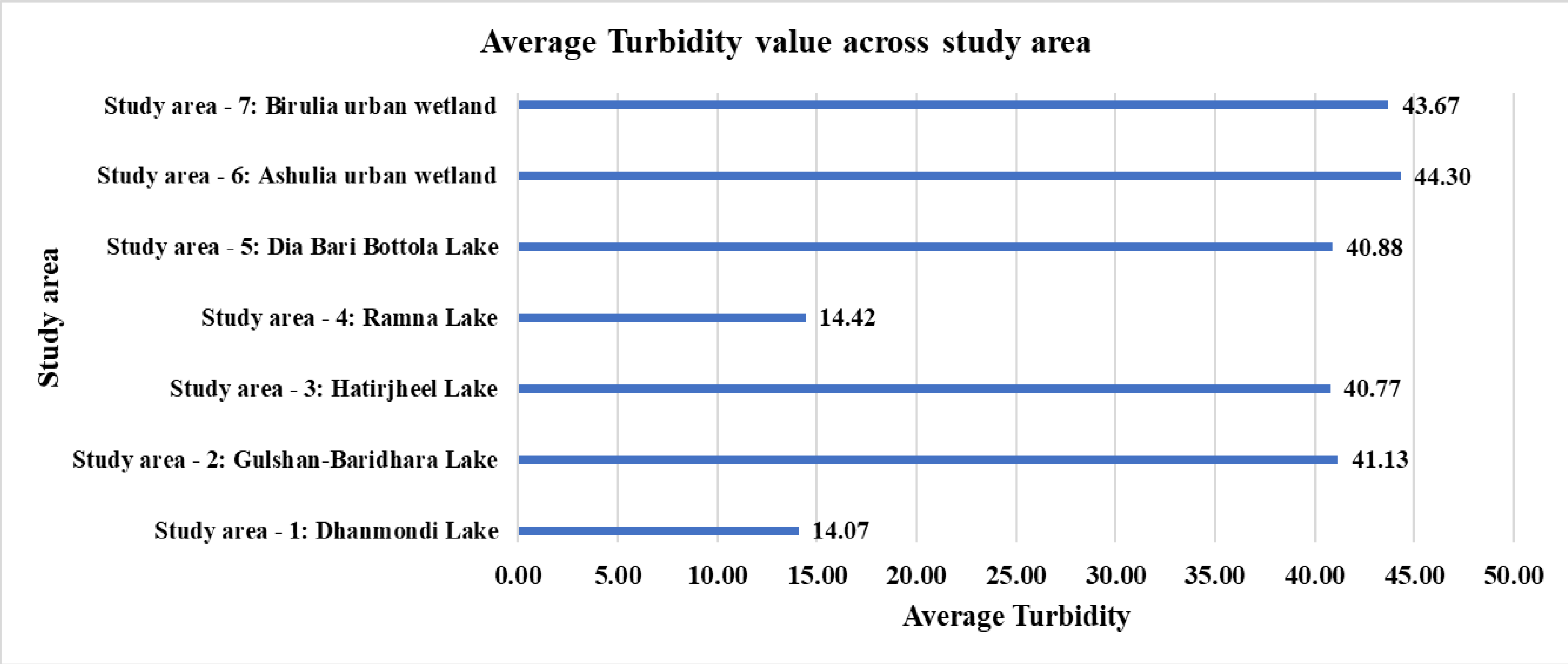


Figure – 6.12: Average Turbidity value across study area

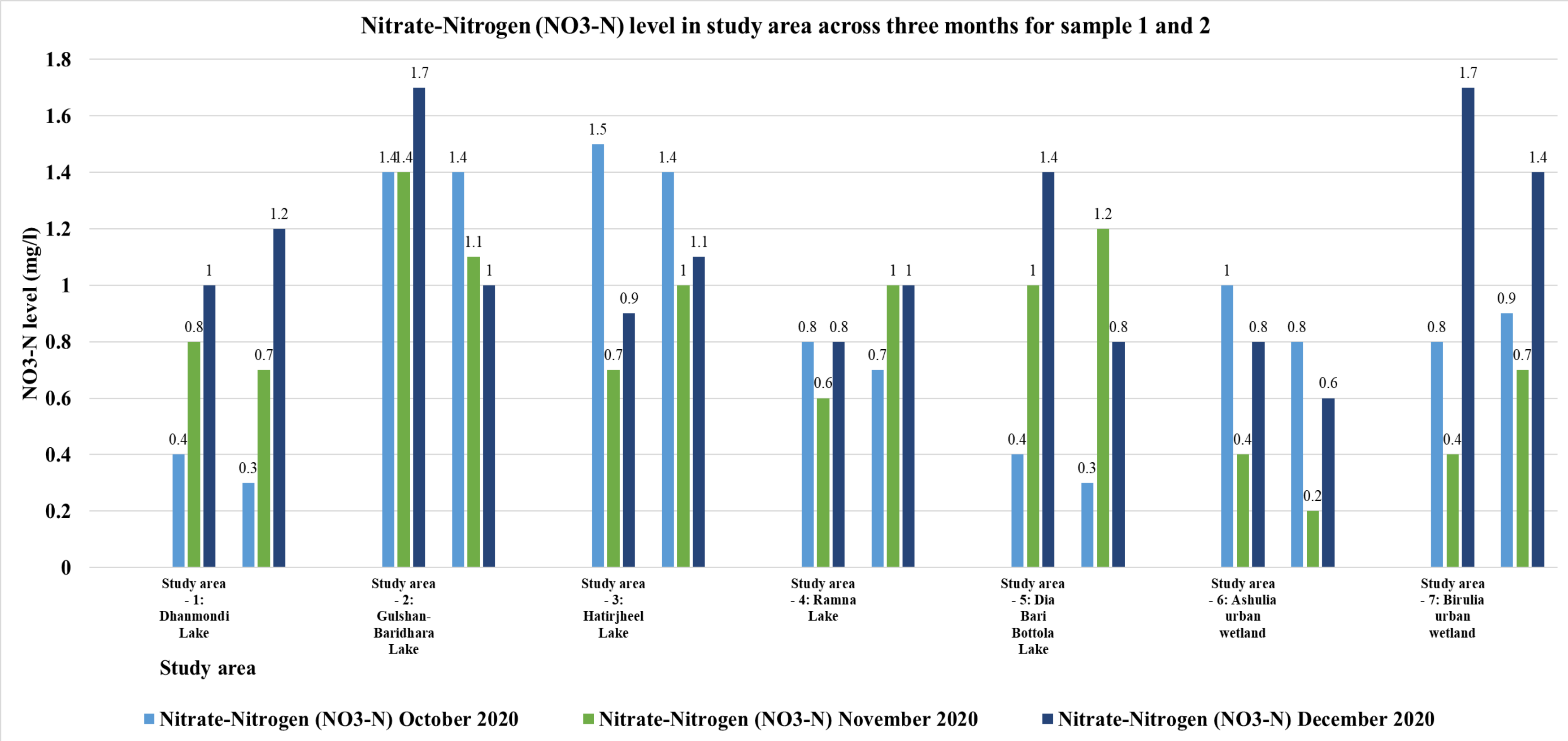


Figure – 6.13: Nitrate-Nitrogen (NO3-N) level in study area across three months for sample 1 and 2

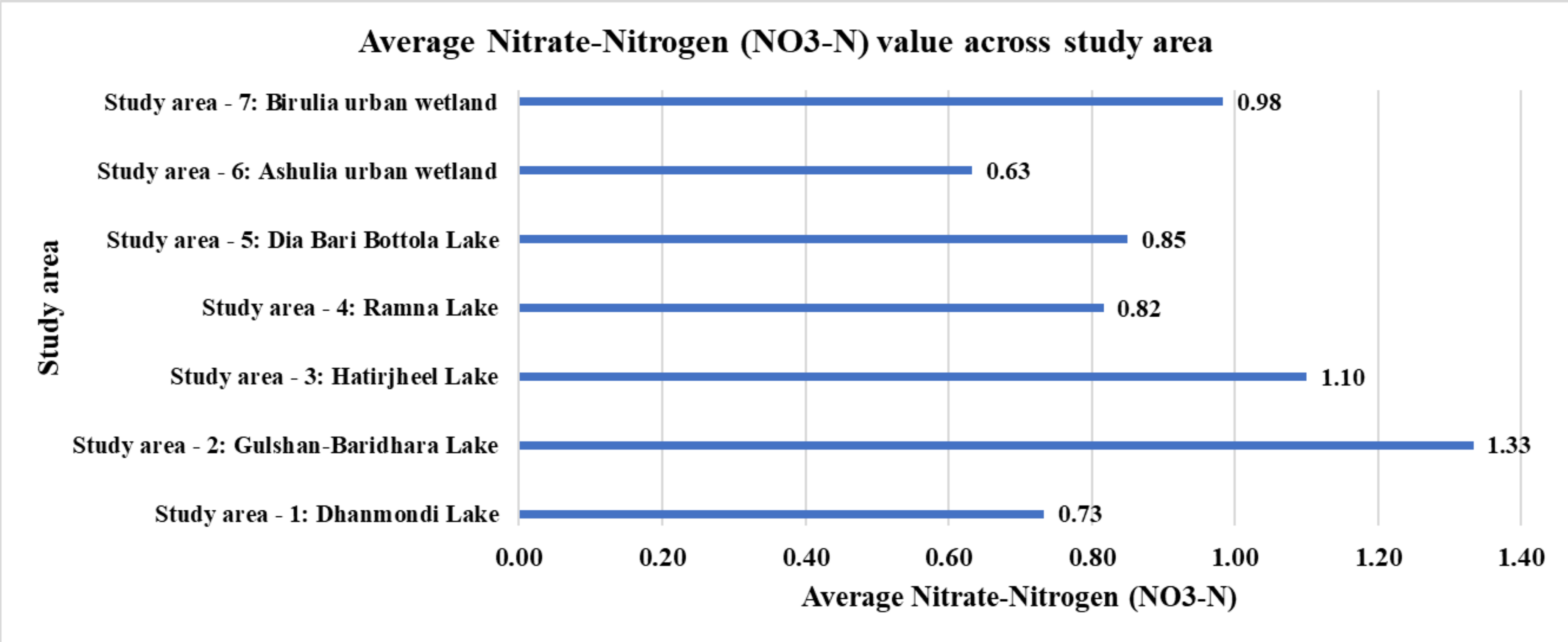


Figure – 6.14: Average Nitrate-Nitrogen (NO3-N) value across study area

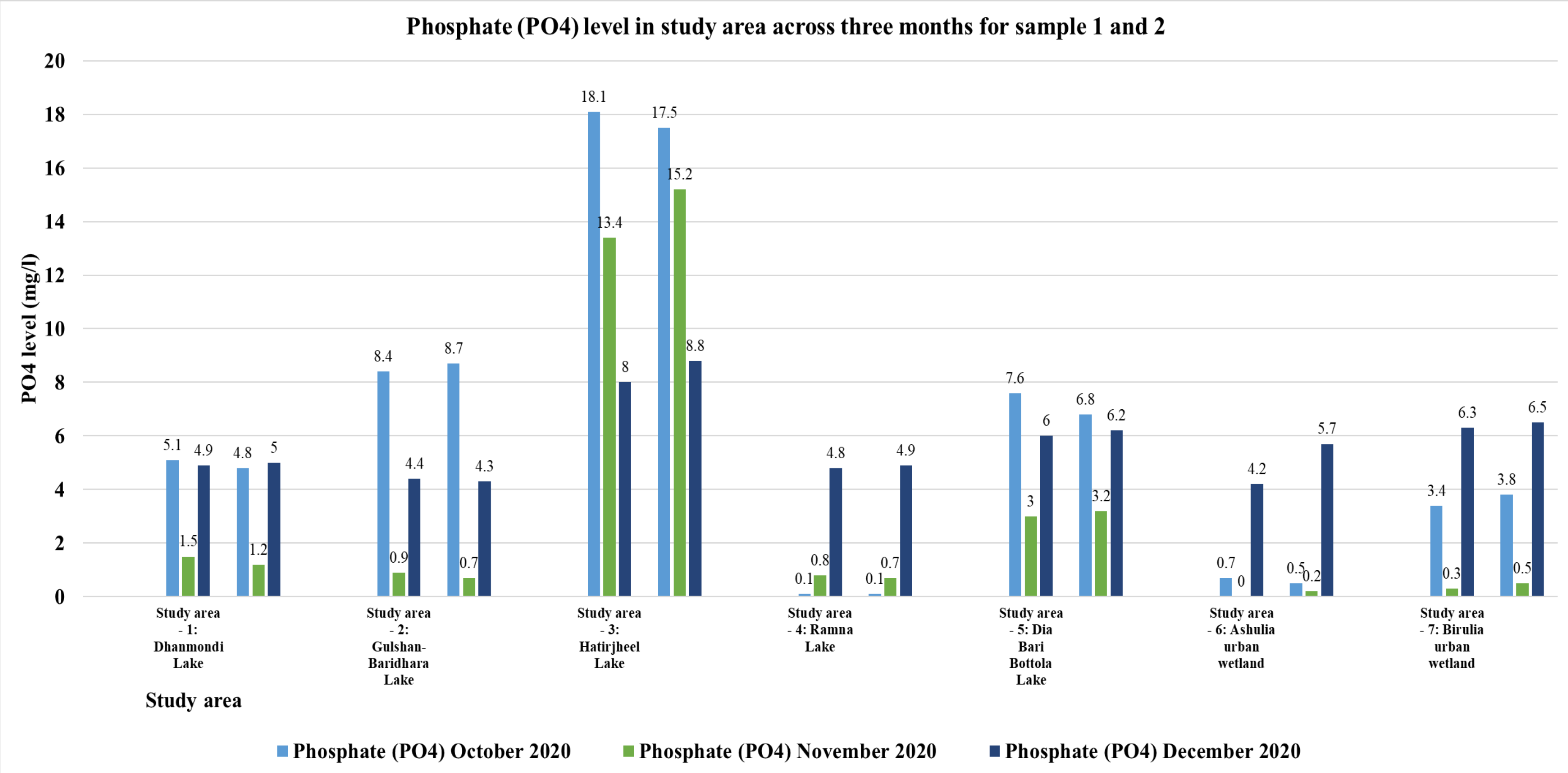


Figure – 6.15: Phosphate (PO4) level in study area across three months for sample 1 and 2

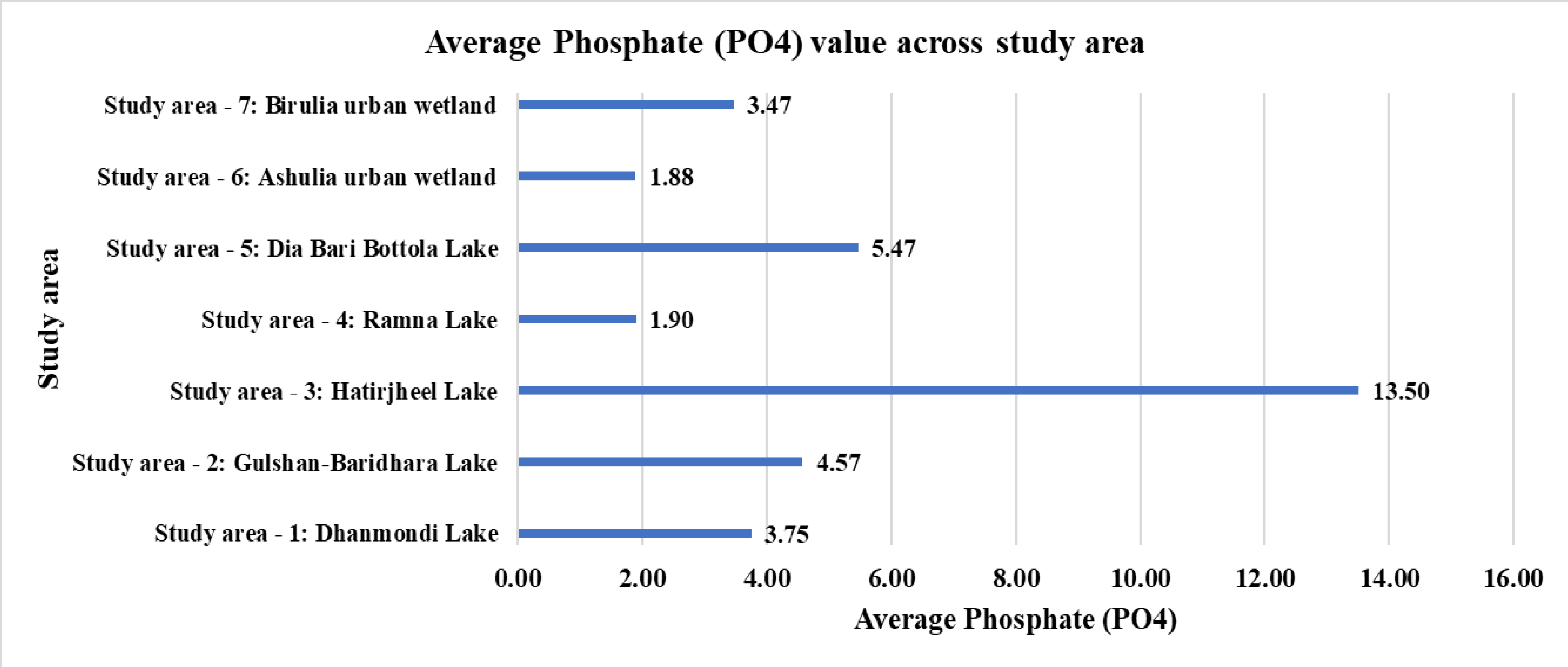


Figure – 6.16: Average Phosphate (PO4) value across study area

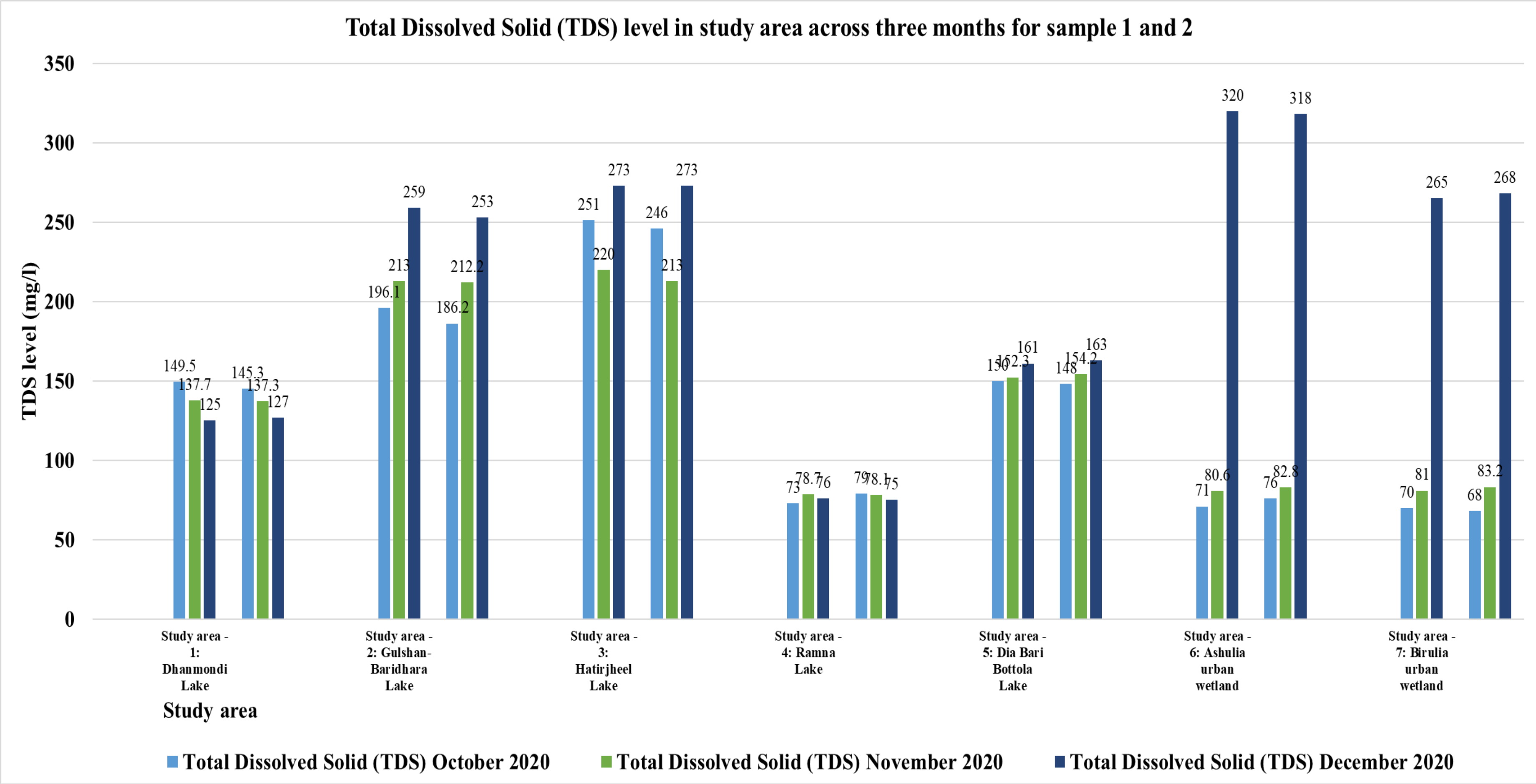


Figure – 6.17: Total Dissolved Solid (TDS) level in study area across three months for sample 1 and 2

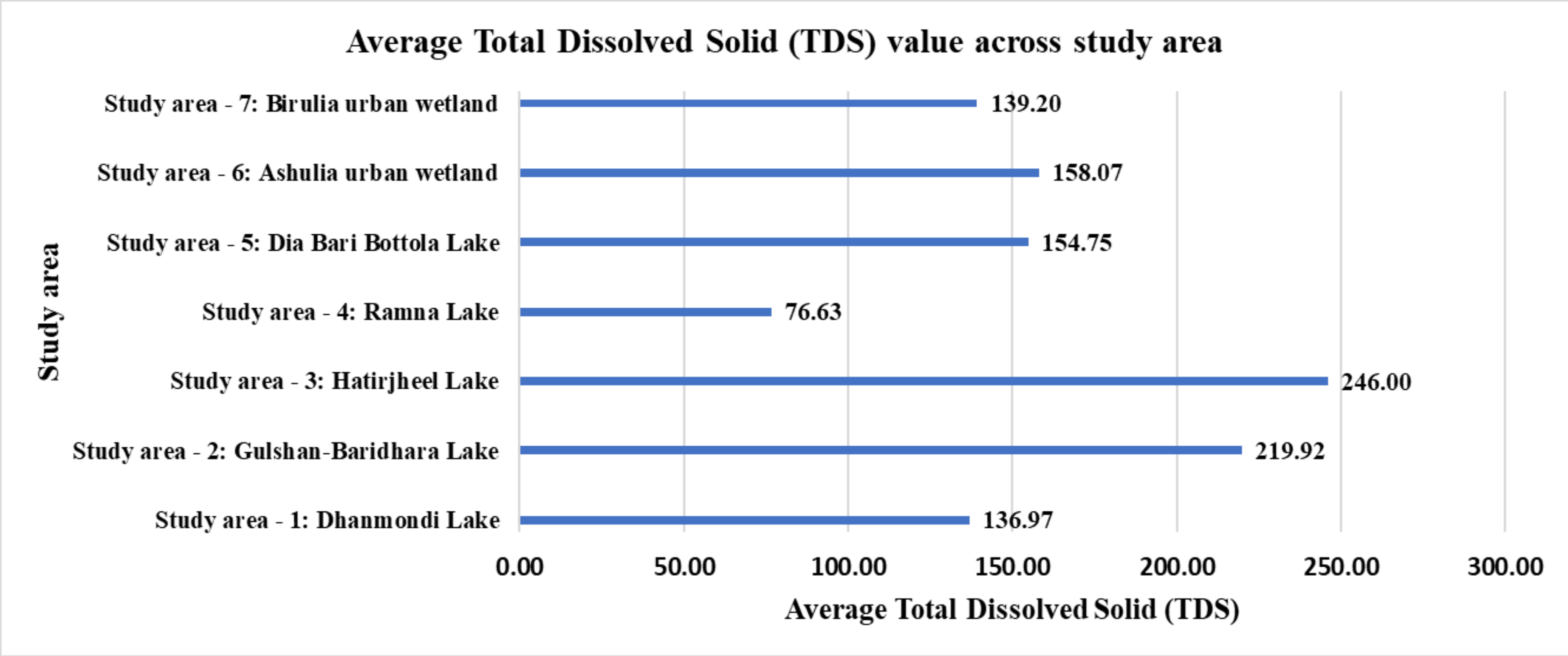


Figure – 6.18: Average Total Dissolved Solid (TDS) value across study area

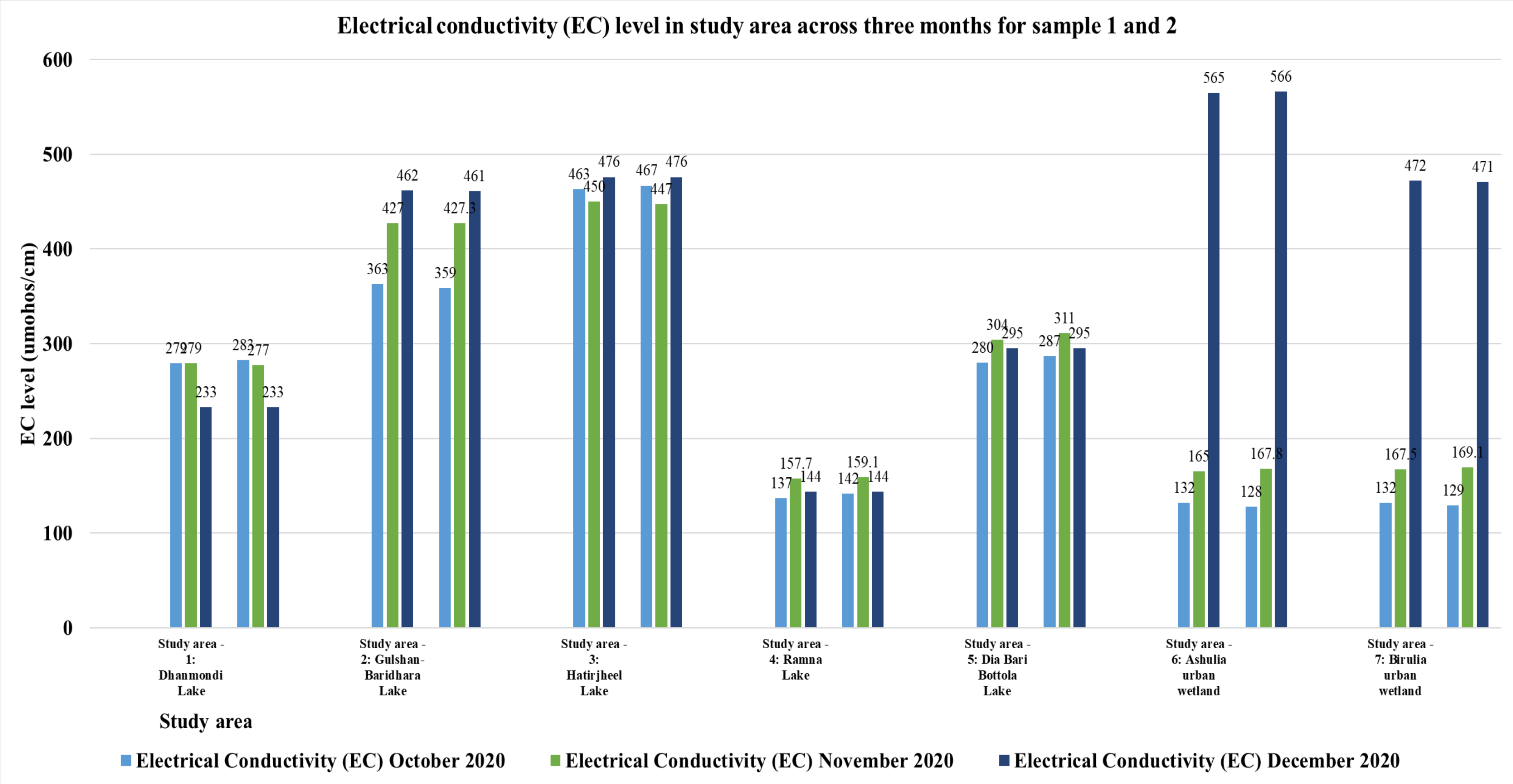


Figure – 6.19: Electrical Conductivity (EC) level in study area across three months for sample 1 and 2

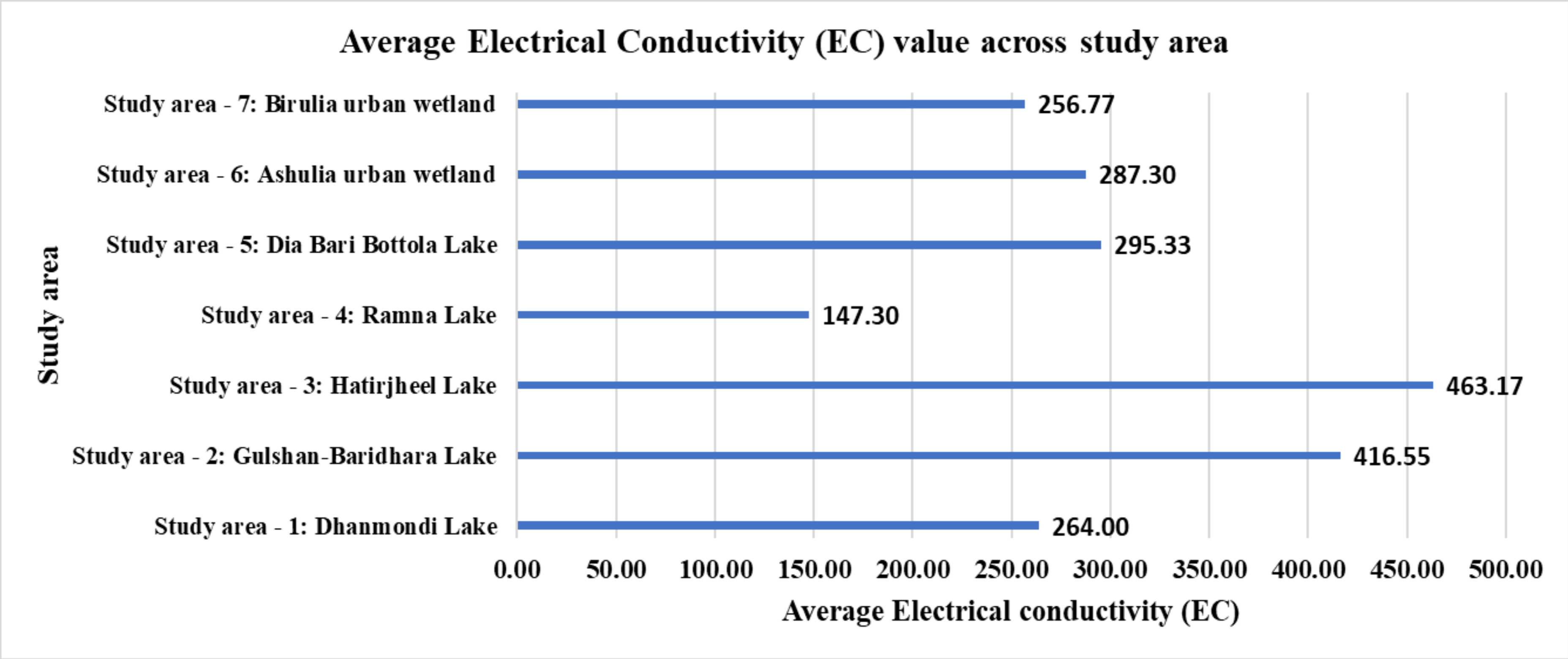


Figure – 6.20: Average Electrical Conductivity (EC) value across study area

5.2 Concluding Remarks

This chapter discussed the results of water quality assessment in study area.

CHAPTER - VII

FINDINGS AND ANALYSIS – 4

This chapter discussed the results of external factors and how these factors affecting the variation of Dissolved Oxygen (DO) concentration across study area by the author personal field observation according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 2' that followed by the fourth objective and fourth research question of the study.

7.1 Applicability of the Urban Wetland Sustainability Framework (UWSF) Model – 2 Across Study Area Context

This section of the research further identified the external factors and how these factors affecting the variation of Dissolved Oxygen (DO) concentration across study area on the context of Dhaka city according to 'Urban Wetland Sustainability Framework (UWSF) Model – 2' that have been developed in this research and already discussed in the Chapter - II: Literature Review and Analytical Framework and Chapter - III: Methodology and Study Area. This section tried to identified the fourth research question answers. The research questions is **(4) w**hat are the external factors and how these factors have been influencing the variation of Dissolved Oxygen (DO) concentration across selected urban wetlands in Dhaka according to Urban Wetland Sustainability Framework (UWSF) Model - 2? To identify the above research question, all information has been identified by the author personal field observation as follows. This information can contribute to the sustainability of urban wetland management from the perspective of water quality by using an important indicator of Dissolved Oxygen (DO) concentration. This information will further help to implement the future sustainable policy and management plan on specific wetland areas in the city and throughout the country.

7.1.1 External Factors Influencing the Variation of Average Dissolved Oxygen (DO) Concentration Across Selected Urban Wetlands

Urban wetlands have been playing the most valuable ecosystem in the capital city of Dhaka from long time. These water bodies have been hosting a wide variety of aquatic habitats. But these urban wetland ecosystems have been facing a growing impact of natural and anthropogenic external factors due to increasing stresses of urban development, high population growth, climate change and other threats in the city. As a result, the water quality of maximum urban wetlands has been affecting negatively by these external factors directly or indirectly in the capital. The status of aquatic environment and ecosystem of maximum urban wetlands have been interrupted by Dissolved Oxygen (DO) depletion. Therefore, it is important to identify these external factors that have been influencing the variation of Dissolved Oxygen (DO) on the selected urban wetland degradation. Under these circumstances, six external factors have been selected to how these factors are influencing on the variation of average DO concentration in study areas. These external factors are water pollution from sewerage effluent, water pollution from industrial effluent, population density, presence of surrounding shaded trees and vegetations, air pollution and existing wetland management structures etc. To what extent these external factors are affecting the average DO level of water, we have divided the level of influence into three categories as low (1), medium (2) and high (3) for the analysis. Following (Table – 7.1) showed the selection criteria for the level of influence of external factors influencing the variation of average Dissolved Oxygen (DO) concentration across urban wetlands. External factors influencing the variation of average Dissolved Oxygen (DO) concentration across each study area have been discussed in (Table – 7.2, 7.3, 7.4, 7.5, 7.6, 7.7 and 7.8). The level of influence of external factors on the variation of average Dissolved Oxygen (DO) concentration across selected urban wetlands have been indicated in (Table – 7.9). Six external factors as water pollution from sewerage effluent, water pollution from industrial effluent, population density, presence of surrounding shaded trees and vegetations, air pollution and existing wetland management structures etc. influencing the variation of average Dissolved Oxygen (DO) concentration across urban wetlands that indicated by graph in (Figure – 7.1, 7.2, 7.3, 7.4, 7.5 and 7.6). In (Figure – 7.7), a map showing indication of influence on sewerage pollution of selected study area. In (Figure – 7.8), a map showing indication of influence on industrial pollution of selected study area locating industrial cluster. After the analysis, this study also recommended some policies and management plan suggestions in this regard.

Table – 7.1: Selection Criteria for the Level of Influence of External Factors Influencing the Variation of Average Dissolved Oxygen (DO) Concentration Across Urban Wetlands (Source: Author personal field observation; Population density: BBS, (2015-2020))

Sl. no.	External Factors	Level of Influence		
		Low	**Medium**	**High**
01.	**Water pollution from sewerage effluent**	**(a)** Presence of existing conventional sewerage drainage connection **(b)** Presence of open defecation places.	**(a)** Absence of existing conventional sewerage drainage connection **(b)** Presence of pit latrine for sewerage waste disposal **(c)** Presence of open defecation places.	**(a)** Direct or indirect illegal connection of sewerage line to the water body **(b)** Absence of existing proper sewerage drainage connection **(c)** Presence of internal connectivity with other polluted water bodies **(d)** Presence of open defecation places.
02.	**Water pollution from industrial effluent**	**(a)** Absence of existing industries **(b)** Absence of internal connectivity with other polluted water bodies **(c)** Low effluent transmission with the rain water.	**(a)** Presence of existing industries **(b)** Presence of internal connectivity with other polluted water bodies **(c)** Effluent transmission with the rain water.	**(a)** High industrial areas **(b)** Presence of internal connectivity with other highly polluted water bodies **(c)** Effluent transmission with the rain water.
03.	**Population density (persons/km2)**	1,500 to 5,000	20,000 to 30,000	40,000 to 60,000
04.	**Presence of surrounding shaded trees and vegetations**	**(a)** Absence of shaded trees and vegetations **(b)** High rise of the atmospheric temperature **(c)** High sediment accumulation.	**(a)** Medium presence of shaded trees and vegetations **(b)** Newly planted areas **(c)** Medium sediment accumulation.	**(a)** Surrounded with huge shaded trees, vegetations and wetland park **(b)** Lower the atmospheric temperature **(c)** Lower sediment accumulation.
05.	**Air pollution**	**(a)** Air pollution from light traffic vehicular movement areas **(b)** Newly developed areas **(c)** Water body surrounded by huge shaded trees and vegetations and wetland park areas.	**(a)** Air pollution from medium traffic vehicular movement areas, commercial areas, water vessels etc.	**(a)** Air pollution from high traffic vehicular movement areas, industrial, brick kilns, construction areas. commercial areas, water vessels etc.
06.	**Existing wetland management structures**	**(a)** Lack of management on the sewerage and industrial pollution **(b)** Lack of management on the visitor and local people pollution by throwing waste in the water body **(c)** Limited contribution and capacity of relevant authorities.	**(a)** Lack of management on the visitor and local people pollution by throwing waste in the water body.	**(a)** Good management of sewerage and industrial pollution **(b)** Strict maintenance on the visitor and local people pollution by throwing waste in the water body.

Table – 7.2: External factors influencing the variation of average Dissolved Oxygen (DO) concentration across Study area – 1: Dhanmondi Lake

Sl. no.	Selected urban wetlands	Average Dissolved Oxygen (DO) concentration (mg/l)	External Factors					
			Water pollution from sewerage effluent	**Water pollution from industrial effluent**	**Population density (persons/ km2)**	**Presence of surrounding shaded trees and vegetations**	**Air pollution**	**Existing wetland management structures**
01.	**Study area - 1: Dhanmondi Lake**	**7.03**	**(Low)** **(a)** As the presence of existing conventional sewerage drainage connection **(b)** Open defecation places of human and animal excreta can transmit with the rain water during the monsoon and can degrade the water body with microbial and other contamination without any kind of treatment.	**(Low)** **(a)** There is absence of industries surrounding the water body **(b)** It is a closed water body and do not have internal connection with other water bodies **(c)** Low concentration of industrial effluent can transmit with the rain water during the monsoon from other areas of the city without any kind of treatment.	**(High) 45,994.70** **(a)** High population density has been demanding higher urban development, creating higher anthropogenic pressures and obstructions on the water quality of the water body.	**(High)** **(a)** Both bank of the water body has been surrounded by huge green canopy of shaded trees and vegetation **(b)** Presence of these significant green spaces have been contributing lower the atmospheric temperature of surrounding area, lower the water temperature and lower the air pollution intensity **(c)** Another way, lower sediment accumulation from surrounding area can positively affect the dissolved	**(Medium)** **(a)** Air pollution mainly from vehicular emission, construction yards etc. have been degrading the water quality of the lake.	**(Medium)** **(a)** Managed by DSCC, LGI, DWASA, DoF, DoE etc. **(b)** Lack of management on the visitor and local people pollution by throwing waste in the water body.

						oxygen concentration during the monsoon season as well.		

(Source: Developed by the author from field observation)

Table – 7.3: External factors influencing the variation of average Dissolved Oxygen (DO) concentration across Study area – 2: Gulshan-Baridhara Lake

Sl. no.	Selected urban wetlands	Average Dissolved Oxygen (DO) concentration (mg/l)	External Factors					
			Water pollution from sewerage effluent	Water pollution from industrial effluent	Population density (persons/ km2)	Presence of surrounding shaded trees and vegetations	Air pollution	Existing wetland management structures
02.	**Study area - 2: Gulshan-Baridhara Lake**	3.03	**(High)** **(a)** As sewerage line illegally directly and indirectly connected to this water body without any kind of treatment **(b)** As the absence of proper existing sewerage drainage network connection surrounding the water body areas **(c)** Hatirjheel Lake internally connected to this Lake **(d)** Open defecation places of human and animal excreta can transmit with the	**(High)** **(a)** As Hatirjheel Lake internally connected to the Gulshan-Baridhara Lake and high concentration of industrial effluent can transmit from Tejgaon industrial area **(b)** Industrial effluent can transmit from other areas of the city with the rain water during the monsoon and can degrade the water body without any kind of treatment.	**(Medium) 29,186.85** **(a)** Medium population density indicating medium human induced pressures on the water quality of the water body.	**(Medium)** **(a)** Gulshan Bank side of the water body have been surrounded by huge green canopy of shaded trees and vegetation but less amount are present on the Badda Bank side **(b)** These lower intensity of green spaces on the Badda bank side have been affecting rise of the atmospheric temperature of surrounding area, affecting the water temperature and air pollution intensity negatively **(c)** Another way,	**(High)** **(a)** Air pollution mainly from vehicular emission, commercial setup, construction yards etc. have been degrading the water quality of the lake.	**(Low)** **(a)** Managed by RAJUK, LGI, DoF, DoE etc. **(b)** Lack of management on the sewerage and industrial pollution **(c)** Lack of management on the visitor and local people pollution by throwing waste in the water body.

			rain water during the monsoon and can degrade the water body with microbial and other contamination without any kind of treatment.			higher sediment accumulation from Badda Bank surrounding area can negatively affecting the dissolved oxygen concentration during the monsoon season as well.		

(Source: Developed by the author from field observation)

Table – 7.4: External factors influencing the variation of average Dissolved Oxygen (DO) concentration across Study area – 3: Hatirjheel Lake

Sl. no.	Selected urban wetlands	Average Dissolved Oxygen (DO) concentration (mg/l)	External Factors					
			Water pollution from sewerage effluent	Water pollution from industrial effluent	Population density (persons/ km2)	Presence of surrounding shaded trees and vegetations	Air pollution	Existing wetland management structures
03.	Study area - 3: Hatirjheel Lake	5.17	(High) (a) Improper existing sewerage drainage connection presently **(b)** Gulshan Lake internally connected to Hatirjheel Lake. **(c)** Open defecation places of human and animal excreta can transmit with the rain water during the monsoon and can degrade the water body with microbial and other contamination without any kind of treatment.	(High) **(a)** Presence of industries besides the water body. High concentration of industrial effluent has been transmitted from Tejgaon industrial area through different outlets. **(b)** Industrial effluent can transmit from other areas of the city with the rain water during the monsoon and can degrade the water body without any kind of treatment.	(High) 58,368.11 **(a)** High population density have been demanding higher urban development, creating higher anthropogenic pressures on the water quality of the water body.	(Medium) **(a)** At present, both banks of the water body surrounded by green canopy of shaded trees and vegetation that have been planted by the relevant authorities several years back during the re-development phase **(b)** Presence of medium intensity of green spaces have been affecting lower the atmospheric temperature of surrounding area, lower the water temperature and air pollution intensity **(c)** Another way,	(High) **(a)** Air pollution mainly from vehicular emission, industries, commercial setup, construction yards etc. have been degrading the water quality of the lake.	(Low) **(a)** Managed by RAJUK, Bangladesh Army, DoF, DWASA, DoE etc. **(b)** Lack of management on the sewerage and industrial pollution **(c)** Lack of management on the visitor and local people pollution by throwing waste on the bank of the water body sometimes.

						lower sediment accumulation from surrounding area can positively affect the dissolved oxygen concentration during the monsoon season as well.		

(Source: Developed by the author from field observation)

Table – 7.5: External factors influencing the variation of average Dissolved Oxygen (DO) concentration across Study area – 4: Ramna Lake

Sl. no.	Selected urban wetlands	Average Dissolved Oxygen (DO) concentration (mg/l)	External Factors					
			Water pollution from sewerage effluent	Water pollution from industrial effluent	Population density (persons/ km2)	Presence of surrounding shaded trees and vegetations	Air pollution	Existing wetland management structures
04.	**Study area - 4: Ramna Lake**	8.22	**(Low)** **(a)** As the presence of existing conventional sewerage drainage connection **(b)** All activities of open defecation have been banned by the local people within park area **(c)** Open defecation places of human and animal excreta from outside the park boundary can transmit with the rain water during the monsoon and can degrade the water body with microbial and	**(Low)** **(a)** There is absence of industries surrounding the water body **(b)** It is a closed water body and do not have internal connection with other water bodies **(c)** Some concentration of industrial effluent can transmit with the rain water during the monsoon from other areas of the city without any kind of treatment.	**(High) 54,910.66** **(a)** High population density indicating higher anthropogenic pressures on the water quality of the water body.	**(High)** **(a)** Surrounded by large wetland park of huge green canopy of shaded trees and vegetation **(b)** Presence of significant green spaces of wetland park have been contributing lower the atmospheric temperature of surrounding area, lower the water temperature and air pollution intensity **(c)** Another way, lower sediment accumulation from surrounding huge green areas can positively affect the dissolved oxygen	**(Low)** **(a)** Air pollution mainly from vehicular emission, construction yards etc., but the intensity can be lower as the water body surrounded by large wetland park of huge green canopy of shaded trees and vegetation.	**(High)** **(a)** Managed by PWD, DoF, DWASA etc. **(b)** Good management of sewerage and industrial pollution **(c)** Strict maintenance on the visitor and local people pollution by throwing waste in the water body.

			other contamination without any kind of treatment.			concentration during the monsoon season as well.		

(Source: Developed by the author from field observation)

Table – 7.6: External factors influencing the variation of average Dissolved Oxygen (DO) concentration across Study area – 5: Diabari Bottola Lake

Sl. no.	Selected urban wetlands	Average Dissolved Oxygen (DO) concentration (mg/l)	External Factors					
			Water pollution from sewerage effluent	Water pollution from industrial effluent	Population density (persons/ km2)	Presence of surrounding shaded trees and vegetations	Air pollution	Existing wetland management structures
05.	**Study area - 5: Diabari Bottola Lake**	6.77	**(Low)** **(a)** As the presence of existing sewerage drainage connection (improved on-site sanitation system) **(b)** Open defecation places of human and animal excreta from surrounding areas can transmit with the rain water during the monsoon and can degrade the water body with microbial and other contamination without any kind of treatment.	**(Low)** **(a)** Absence of existing industries surrounding the water body **(b)** Turag River internal connection has been closed by gate during the re-development phase **(c)** Some concentration of industrial effluent can transmit with the rain water during the monsoon from other areas of the city without any kind of treatment.	**(Medium) 20,101.34** **(a)** Medium population density indicating medium human induced pressures on the water quality of the water body. But the intensity is comparatively low as lake area is a open space with very low existing human settlement. People have been living not the adjacent to the lake area	**(Low)** **(a)** Trees have been newly planted by the relevant authorities within recent years as this area has been newly developed area **(b)** Absence of shaded trees have been affecting rise of atmospheric temperature of surrounding area, impacting on the water temperature and air pollution intensity negatively **(c)** Another way, sediment accumulation from surrounding area can affect the dissolved oxygen	**(Low)** **(a)** Lower intensity of air pollution mainly from construction yards, light traffic vehicular movement and emission as this area has been newly developed area.	**(High)** **(a)** Managed by RAJUK, LGI, DoF, DWASA etc. **(b)** Good management of sewerage and industrial pollution **(c)** Strict maintenance on the visitor and local people pollution by throwing waste in the water body.

					and far from the wetland.	concentration during the monsoon season as well.		

(Source: Developed by the author from field observation)

Table – 7.7: External factors influencing the variation of average Dissolved Oxygen (DO) concentration across Study area – 6: Ashulia urban wetland

Sl. no.	**Selected urban wetlands**	**Average Dissolved Oxygen (DO) concentration (mg/l)**	**External Factors**					
			Water pollution from sewerage effluent	**Water pollution from industrial effluent**	**Population density (persons/ km2)**	**Presence of surrounding shaded trees and vegetations**	**Air pollution**	**Existing wetland management structures**
06.	**Study area - 6: Ashulia urban wetland**	5.64	**(Medium)** **(a)** Absence of existing conventional sewerage drainage network connection surrounding the water body areas **(b)** Local village people has been using pit latrine for sewerage waste disposal **(c)** Open defecation places of human and animal excreta can transmit with the rain water during the monsoon and can degrade the water body with microbial and	**(High)** **(a)** Presence of industries near the water body. Industrial effluent from surrounding Ashulia areas of dyeing, textile, chemical and other industries disposed in Turag River and transmit during rainy season to the Ashulia floodplain **(b)** Another way, Turag River is internally connected to the Buriganga, Karnatali, Dhaleswari, Bangshi, Balu, Lakhya River,	**(Low) 4,726.00** **(a)** Low population density indicating comparatively less human induced pressures on the water quality of the water body.	**(Low)** **(a)** Absence of shaded trees and vegetation surrounding the water body **(b)** Absence of shaded trees have been affecting rise of atmospheric temperature of surrounding area, impacting on the water temperature and air pollution intensity negatively **(c)** Another way, sediment accumulation from surrounding area can affect the dissolved oxygen concentration during the monsoon	**(High)** **(a)** Air pollution mainly from vehicular emission, existing industries, brick kilns, construction yards, coal dumping sites, water vessels etc. have been degrading the water quality of the lake.	**(Low)** **(a)** Local land owners, lease holders have been managed the water body of their own, maximum land are owned by local people **(b)** Local authority as Union Parishad have limited contribution and capacity for the management **(c)** Lack of management on the sewerage and industrial

			other contamination without any kind of treatment.	Tongi Khal that have been also polluted by industrial effluent as these water bodies receives huge industrial effluent from adjacent areas. These industrial areas as Gazipur, Tongi, Savar, DEPZ, Ghorashal, Tarabo, Narayanganj, Hazaribag, Tejgaon industrial areas of Dhaka city that are internally connected to the Turag River.		season as well.		pollution **(d)** Lack of management on the visitor and local people pollution by throwing waste in the water body.

(Source: Developed by the author from field observation)

Table – 7.8: External factors influencing the variation of average Dissolved Oxygen (DO) concentration across Study area – 7: Birulia urban wetland

Sl. no.	Selected urban wetlands	Average Dissolved Oxygen (DO) concentration (mg/l)	External Factors					
			Water pollution from sewerage effluent	Water pollution from industrial effluent	Population density (persons/ km2)	Presence of surrounding shaded trees and vegetations	Air pollution	Existing wetland management structures
07.	**Study area - 6: Birulia urban wetland**	5.12	**(Medium)** **(a)** Absence of existing conventional sewerage drainage network connection surrounding the water body areas **(b)** Local village people has been using pit latrine for sewerage waste disposal **(c)** Open defecation places of human and animal excreta can transmit with the rain water during the monsoon and can degrade the water body with microbial and	**(High)** **(a)** As Birulia floodplain situated besides the Turag River distributaries, therefore industrial effluent from surrounding Ashulia, Savar, Gazipur, Tongi, DEPZ, Ghorashal, Tarabo, Narayanganj, Hazaribag, Tejgaon areas of Dhaka city are polluting Birulia water body that are internally connected to the Turag River through different water bodies as	**(Low)** **1,598.00** **(a)** Low population density indicating comparatively less human induced pressures on the water quality of the water body.	**(Low)** **(a)** Absence of trees and vegetation surrounding the water body, available only inside the village areas **(b)** Absence of shaded trees have been affecting rise of atmospheric temperature of surrounding area, impacting on the water temperature and air pollution intensity negatively **(c)** Another way, sediment accumulation from surrounding area can affect the dissolved oxygen	**(Medium)** **(a)** Air pollution mainly from construction yards, water vessels etc. have been degrading the water quality of the lake.	**(Low)** **(a)** Local land owners, lease holders have been managed the water body of their own, maximum land are owned by local people **(b)** Local authority as Union Parishad have limited contribution and capacity for the management **(c)** Lack of management on the sewerage and industrial

			other contamination without any kind of treatment.	Buriganga, Karnatali, Dhaleswari, Bangshi, Balu, Lakhya River, Tongi Khal etc.		concentration during the monsoon season as well.		pollution **(d)** Lack of management on the visitor and local people pollution by throwing waste in the water body.

(Source: Developed by the author from field observation)

Table – 7.9: The level of influence of external factors on the variation of average Dissolved Oxygen (DO) concentration across urban wetlands

Sl. No.	Selected urban wetlands	Average Dissolved Oxygen (DO) concentration (mg/l)	External Factors					
			Water pollution from sewerage effluent	Water pollution from industrial effluent	Population density (persons/ km2)	Presence of surrounding shaded trees and vegetations	Air pollution	Existing wetland management structures
01.	Study area - 1: Dhanmondi Lake	7.03						
02.	Study area - 2: Gulshan-Baridhara Lake	3.03						
03.	Study area - 3: Hatirjheel Lake	5.17						
04.	Study area - 4: Ramna Lake	8.22						
05.	Study area - 5: Diabari Bottola Lake	6.77						
06.	Study area - 6: Ashulia urban wetland	5.64						
07.	Study area - 7: Birulia urban wetland	5.12						

Level of influence	Indication
High	
Medium	
Low	

(Source: Developed by the author from field observation)

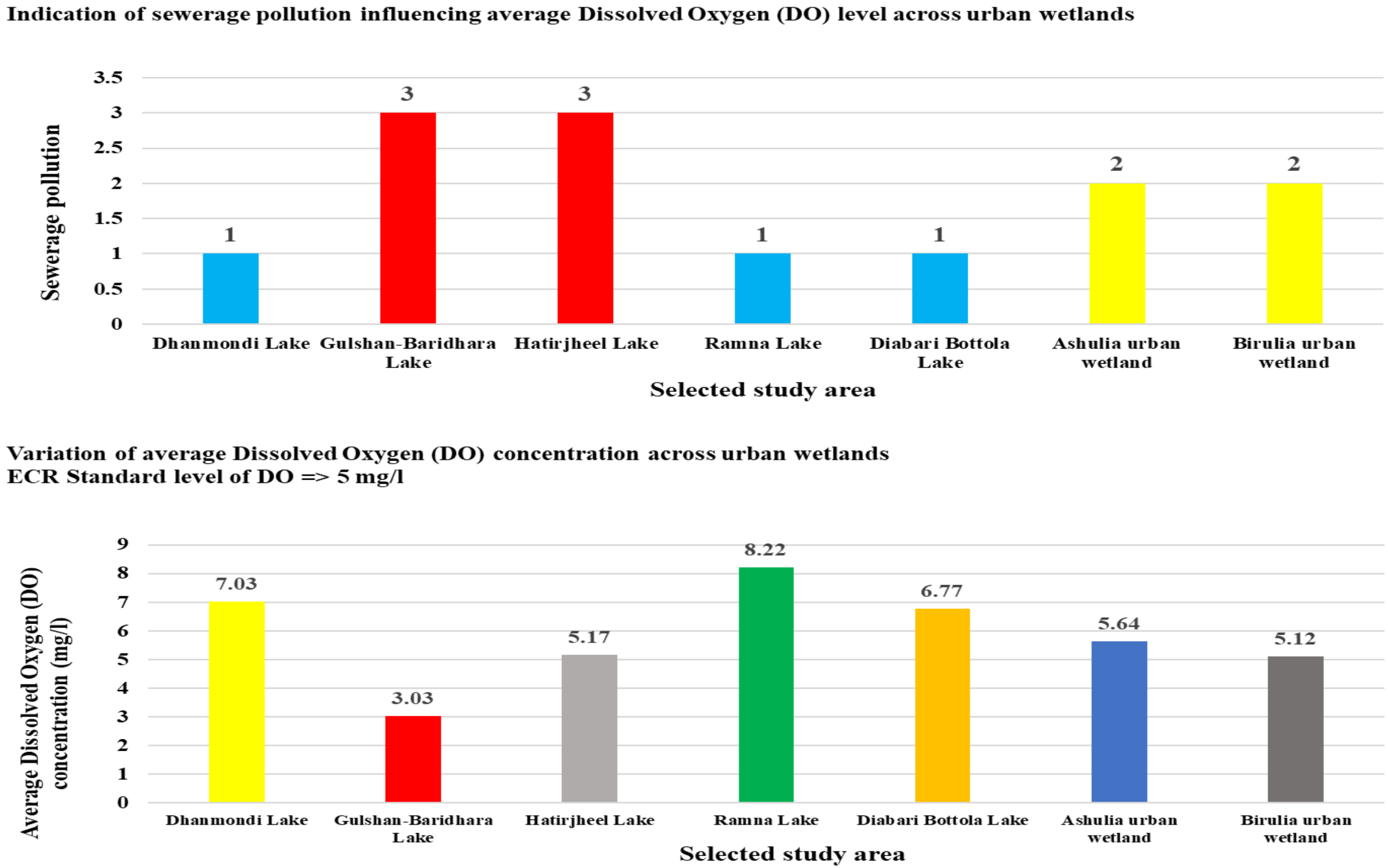
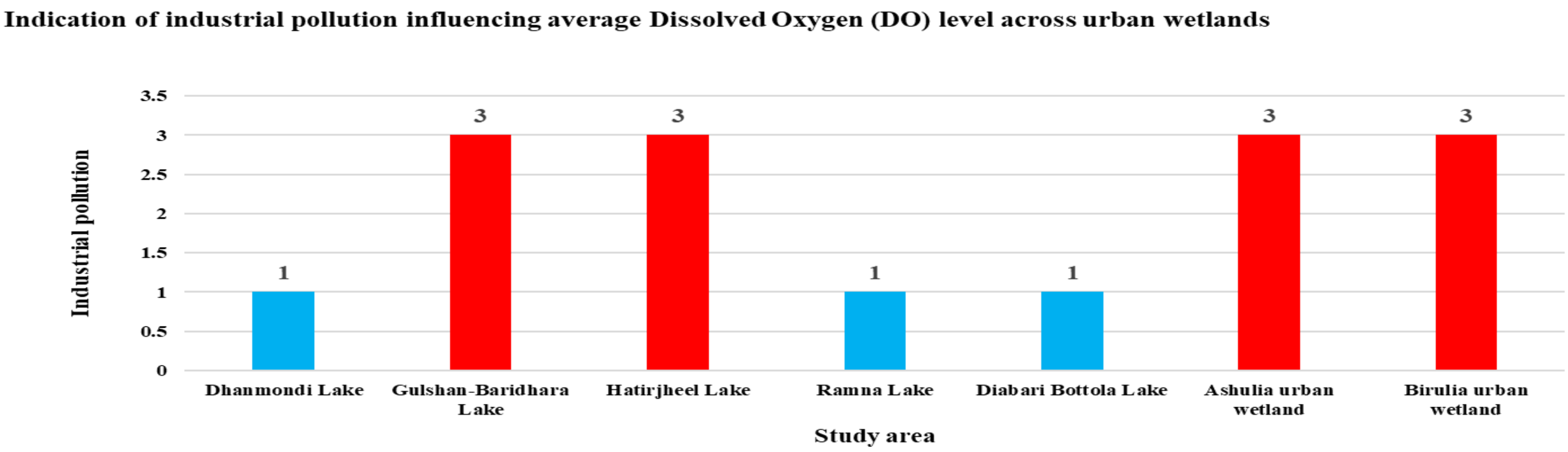


Figure – 7.1: Water pollution from sewerage effluent influencing the variation of average Dissolved Oxygen (DO) concentration across urban wetlands that developed by the author

External factor - 1	Water pollution from sewerage effluent
Study area	**Indication**
Dhanmondi Lake	1
Gulshan-Baridhara Lake	3
Hatirjheel Lake	3
Ramna Lake	1
Diabari Bottola Lake	1
Ashulia urban wetland	2
Birulia urban wetland	2
Low	**1**
Medium	**2**
High	**3**



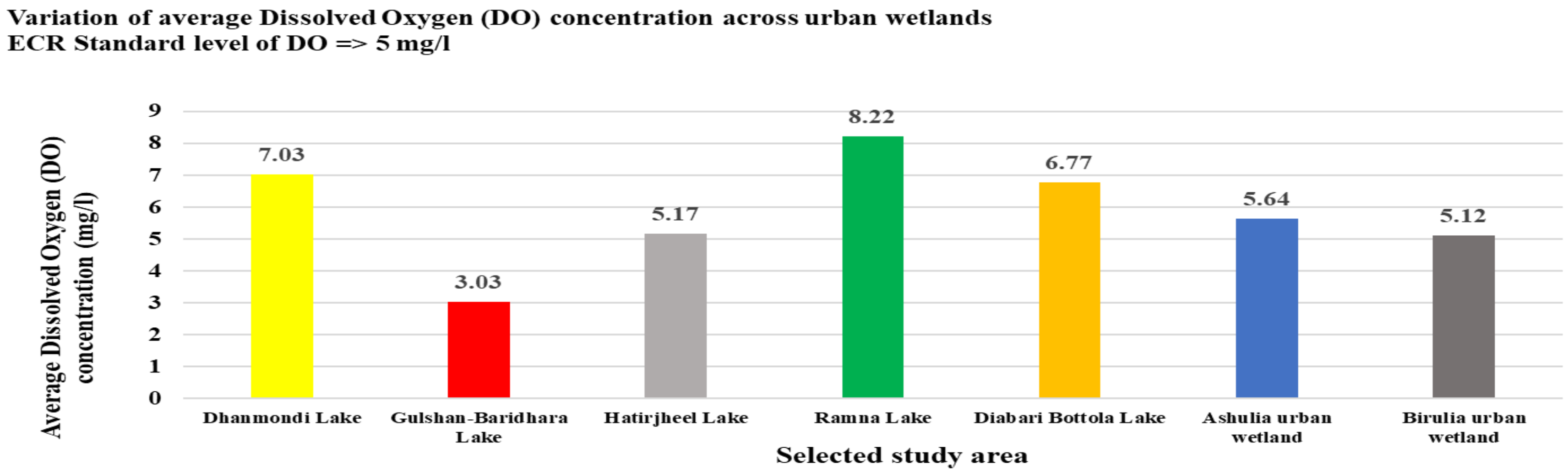
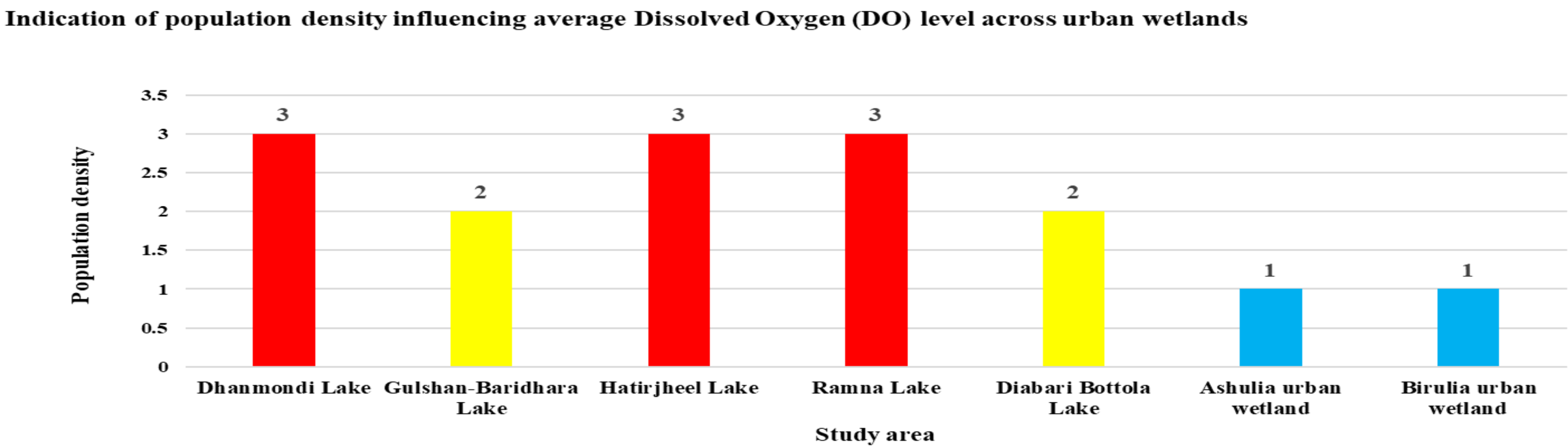


Figure – 7.2: Water pollution from industrial effluent influencing the variation of average Dissolved Oxygen (DO) concentration across urban wetlands that developed by the author

External factor - 2	Water pollution from industrial effluent
Study area	**Indication**
Dhanmondi Lake	1
Gulshan-Baridhara Lake	3
Hatirjheel Lake	3
Ramna Lake	1
Diabari Bottola Lake	1
Ashulia urban wetland	3
Birulia urban wetland	3
Low	**1**
Medium	**2**
High	**3**



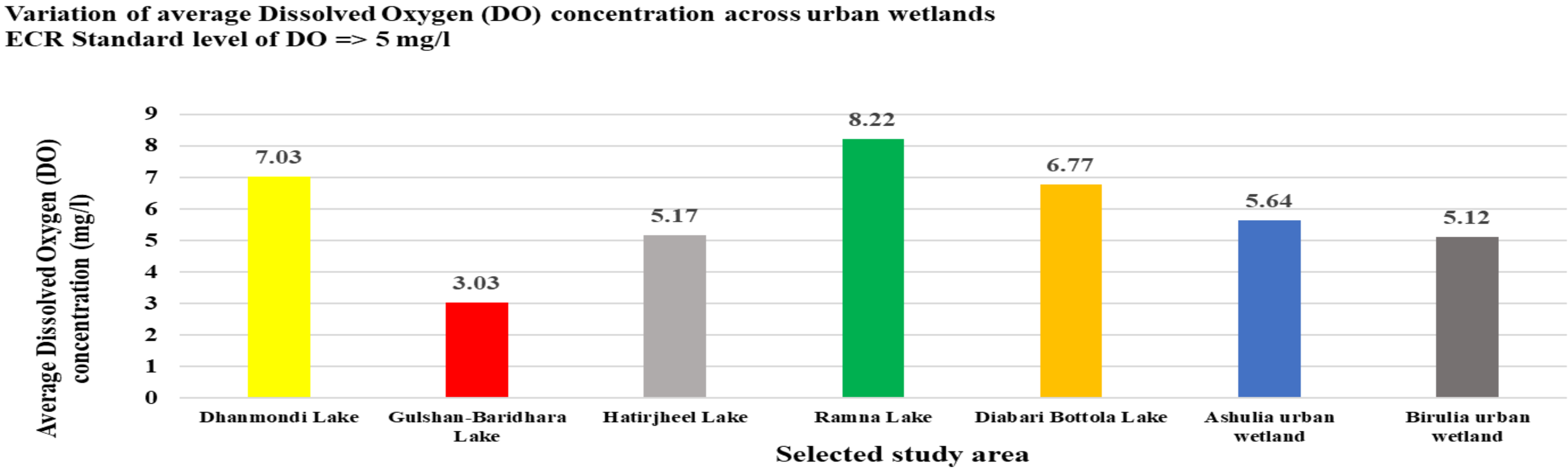
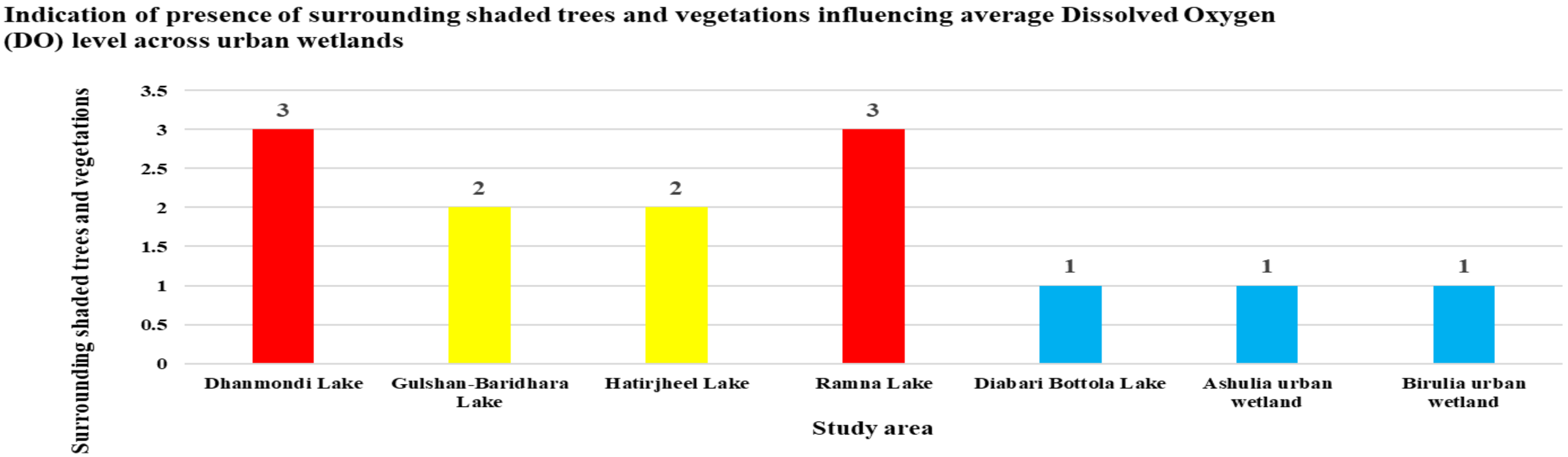


Figure – 7.3: Population density influencing the variation of average Dissolved Oxygen (DO) concentration across urban wetlands that developed by the author

External factor - 3	Population density
Study area	**Indication**
Dhanmondi Lake	3
Gulshan-Baridhara Lake	2
Hatirjheel Lake	3
Ramna Lake	3
Diabari Bottola Lake	2
Ashulia urban wetland	1
Birulia urban wetland	1
Low	**1**
Medium	**2**
High	**3**



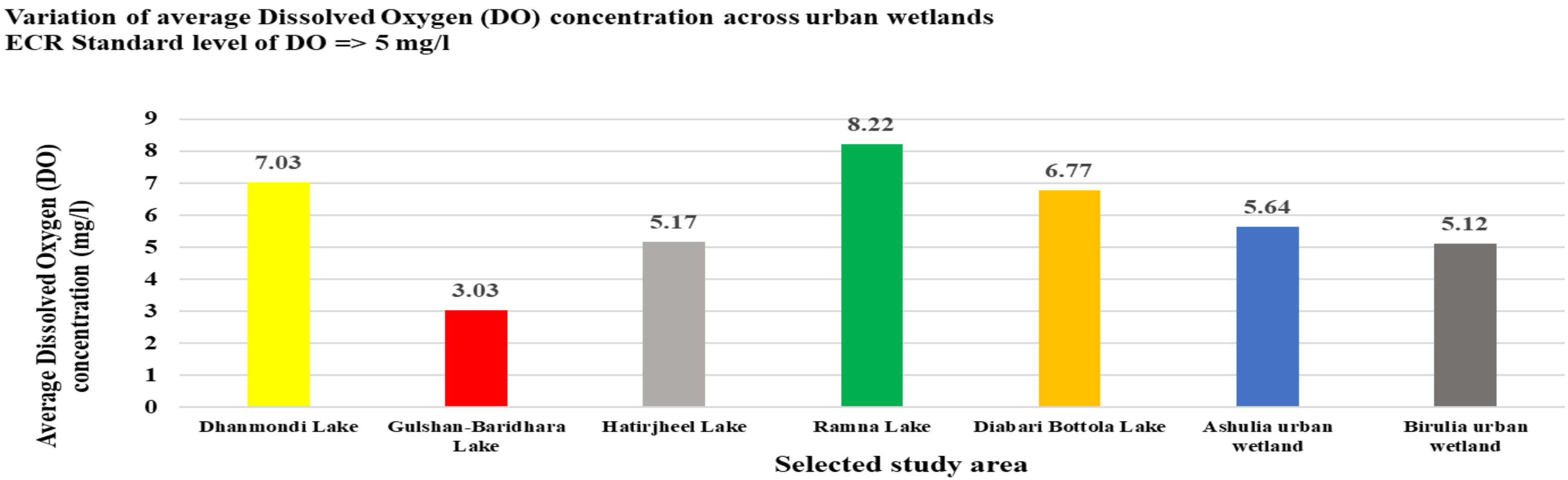


Figure – 7.4: Presence of surrounding shaded trees and vegetations influencing the variation of average Dissolved Oxygen (DO) concentration across urban wetlands that developed by the author

External factor - 4	Presence of surrounding shaded trees and vegetations
Study area	**Indication**
Dhanmondi Lake	3
Gulshan-Baridhara Lake	2
Hatirjheel Lake	2
Ramna Lake	3
Diabari Bottola Lake	1
Ashulia urban wetland	1
Birulia urban wetland	1
Low	**1**
Medium	**2**
High	**3**

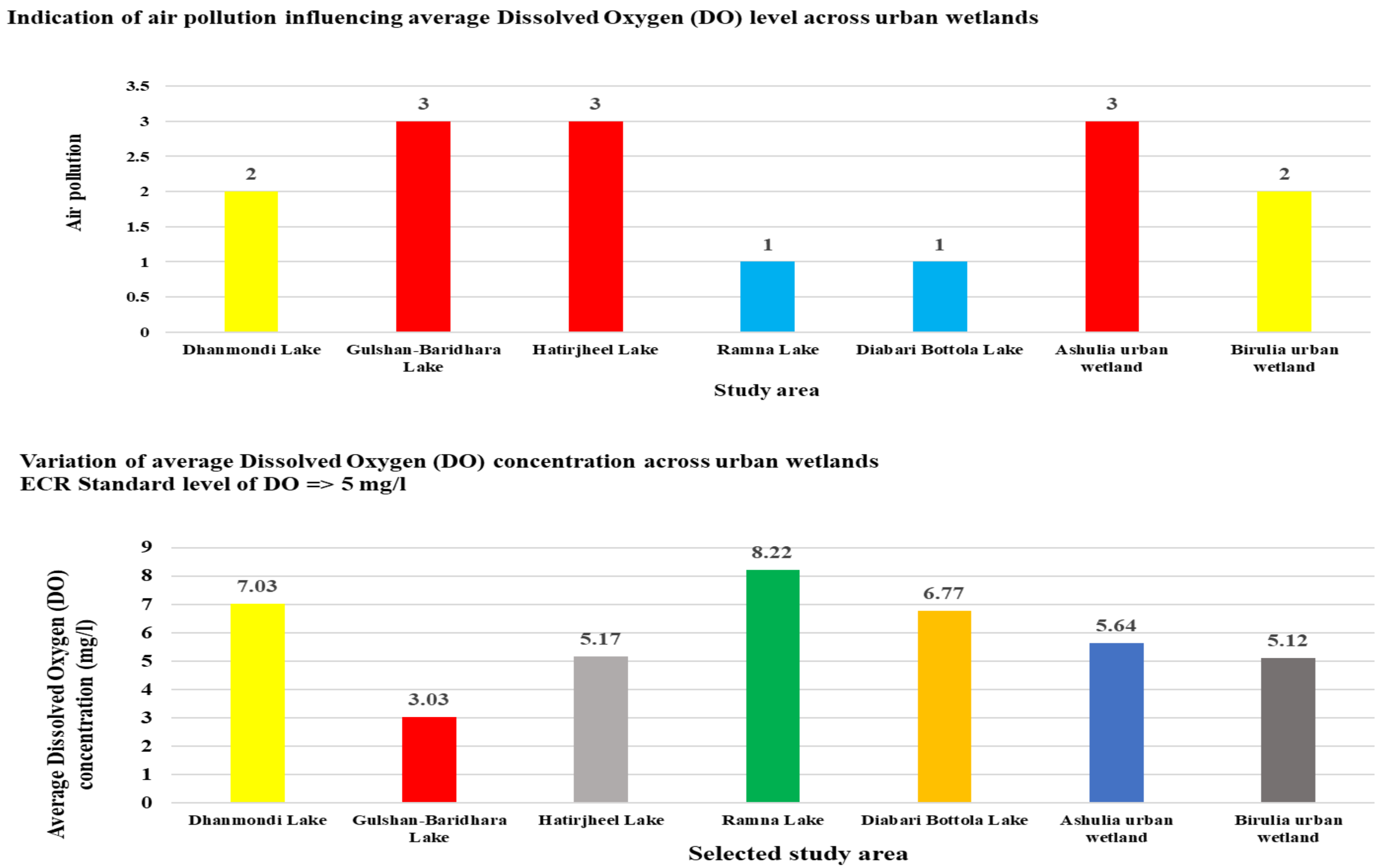


Figure – 7.5: Air pollution influencing the variation of average Dissolved Oxygen (DO) concentration across urban wetlands that developed by the author

External factor - 5	Air pollution
Study area	**Indication**
Dhanmondi Lake	2
Gulshan-Baridhara Lake	3
Hatirjheel Lake	3
Ramna Lake	1
Diabari Bottola Lake	1
Ashulia urban wetland	3
Birulia urban wetland	2
Low	**1**
Medium	**2**
High	**3**

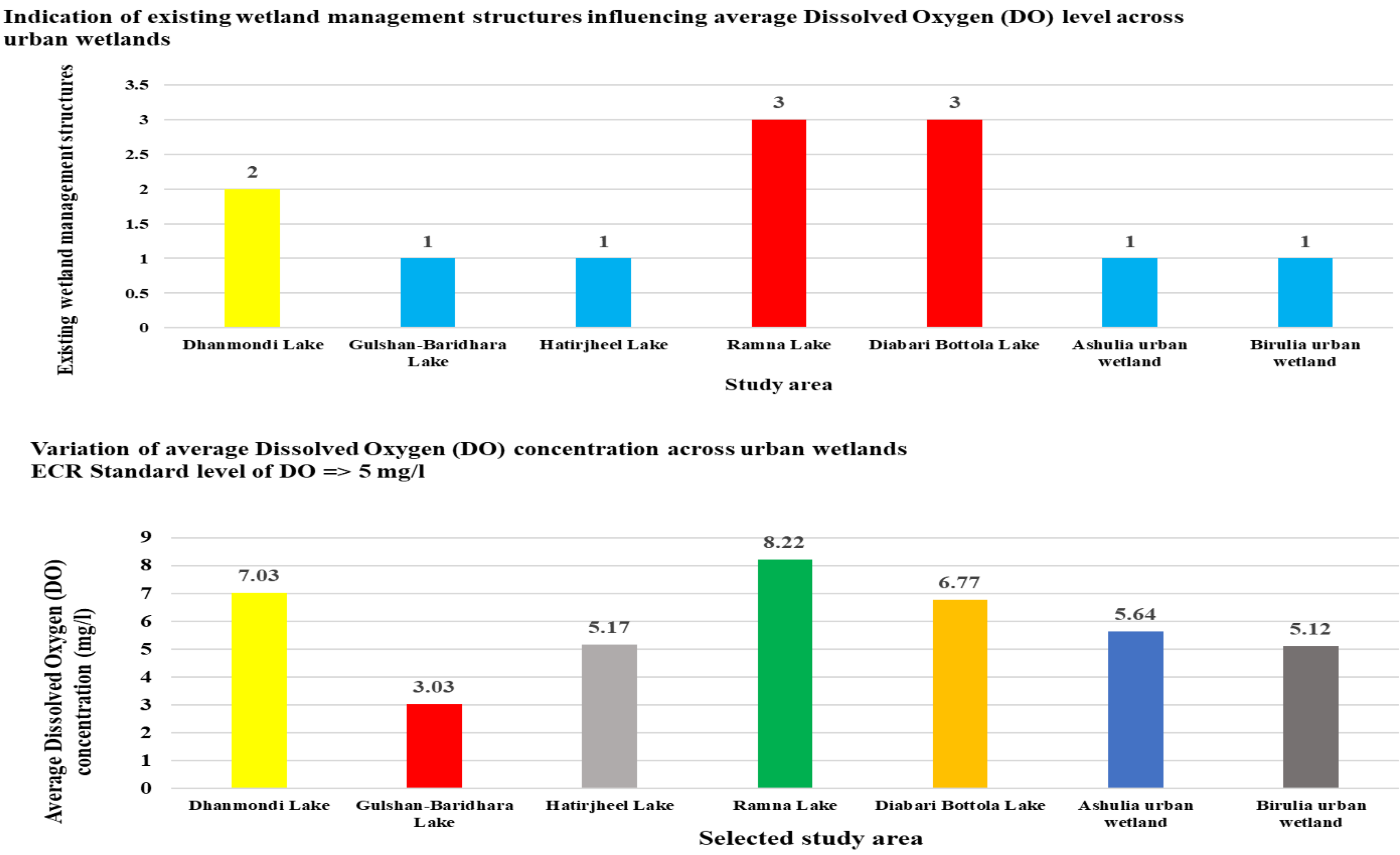


Figure – 7.6: Existing wetland management structures influencing the variation of average Dissolved Oxygen (DO) concentration across urban wetlands that developed by the author

External factor - 6	Existing wetland management structures
Study area	**Indication**
Dhanmondi Lake	2
Gulshan-Baridhara Lake	1
Hatirjheel Lake	1
Ramna Lake	3
Diabari Bottola Lake	3
Ashulia urban wetland	1
Birulia urban wetland	1
Low	**1**
Medium	**2**
High	**3**

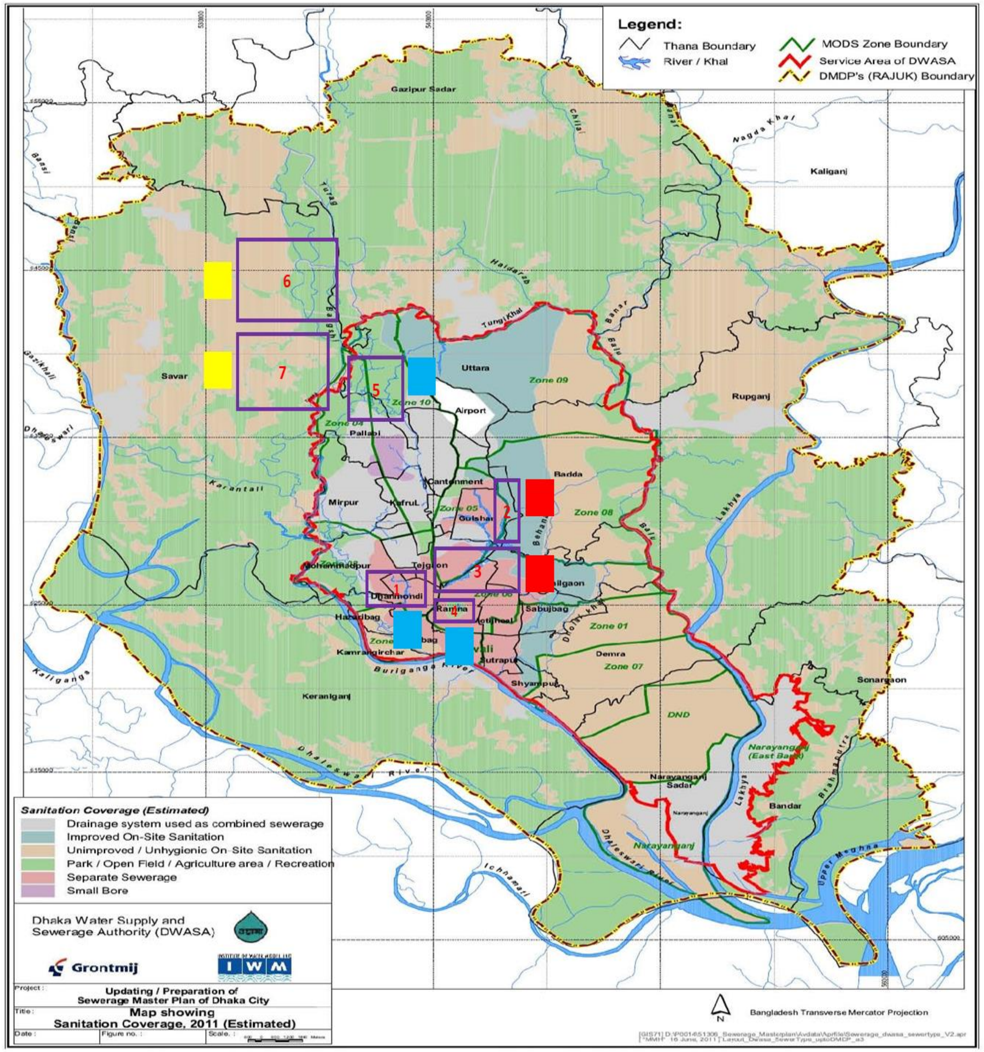


Figure 3.2: Sanitation coverage within RAJUK (DMDP) boundary

Figure – 7.7: Map showing indication of influence on sewerage pollution of selected study area (source: DWASA map (2012), IWM, edited and developed by the author)

Legend of Figure – 7.7

Study area ☐

Study area - 1: Dhanmondi Lake
Study area - 2: Gulshan-Baridhara Lake
Study area - 3: Hatirjheel Lake
Study area - 4: Ramna Lake
Study area - 5: Diabari Bottola Lake
Study area - 6: Ashulia wetland
Study area - 7: Birulia wetland

High influence of sewerage effluent areas

Medium influence of sewerage effluent areas

Low influence of sewerage effluent areas

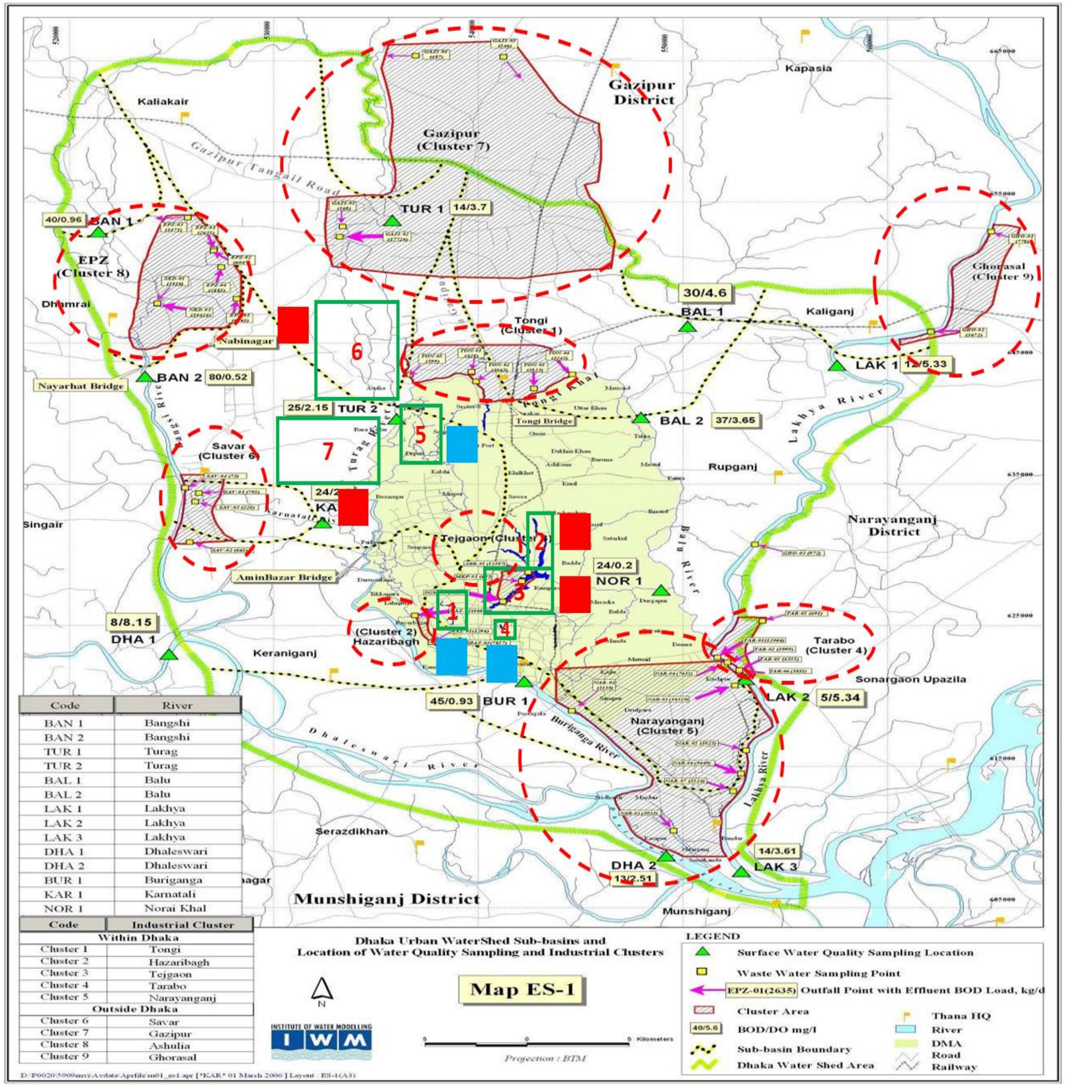


Figure – 7.8: Map showing indication of influence on industrial pollution of selected study area locating industrial cluster (source: DWASA map (2012), IWM, edited and developed by the author)

Legend of Figure – 7.8

Study area

Study area - 1: Dhanmondi Lake
Study area - 2: Gulshan-Baridhara Lake
Study area - 3: Hatirjheel Lake
Study area - 4: Ramna Lake
Study area - 5: Diabari Bottola Lake
Study area - 6: Ashulia wetland
Study area - 7: Birulia wetland

Industry cluster

High influence of industrial effluent areas

Medium influence of industrial effluent areas

Low influence of industrial effluent areas

7.1.1.1 Water Pollution from Sewerage Effluent

There are very few areas in Dhaka city which have been connected with conventional sewerage network systems still now. Improper sewerage line connection has been a regular problem for the urban dwellers in the city that are affecting urban wetland water quality severely. For this external factor of 'sewerage pollution', microbiological contamination of 'fecal coliform concentration' have been selected as an indicator for the cross check with the present research results that identified from other studies. From the above (Table – 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8 and 7.9) and (Figure – 7.1 and 7.7), it appears that, the impact of 'sewerage pollution' on the variation of average Dissolved Oxygen (DO) concentration in **Gulshan-Baridhara** and **Hatirjheel** Lake found **'high'** from the present research.

In Gulshan-Baridhara Lake, according to a study conducted by (Sabit and Ali, 2015), the fecal coliform concentration of the lake was found very high throughout the lake during the study period. Most of the values were TNTC (i.e., Too Numerous To Count) that indicates very high level of fecal pollution which have a similar results with the present study with 'high' 'sewerage pollution'.

In Hatirjheel Lake, a study observed by (Shahjahan and Ahmed, 2016), the fecal coliform concentration of the lake was found in high intensity as 270,000 cfu/100 mL which have a similar result with the present study. Another study conducted on Hatirjheel Lake, by (Majumder et al., 2015), the fecal coliform concentration found in high intensity as 9.17×105 cfu/100 mL, which indicates the water is not safe for human health and this water is vulnerable for diarrhea, dysentery, typhoid fever, shigellosis, salmonellosis, parasitic worm infection, hemolytic uremina syndrome, hepatitis and gastroenteritis etc.

The impact of 'sewerage pollution' on the variation of average DO concentration in **Ashulia** and **Birulia** urban wetland found **'medium'** from the present research. In Ashulia urban wetland, according to a study conducted by (Tahmina et al., 2018), the fecal coliform concentration of the wetland was found 2.01 x103 cfu/100 mL. Other Bacteria as *Escherichia coli*, *Vibrio cholerae*, *Shigella dysenteriae* and *Salmonella typhi* etc. indicating comparatively medium intensity of sewerage pollution and have a similar result with the present study. This same study conducted in Birulia urban wetland sample point and found the fecal coliform concentration was 1.85 x103 cfu/100 mL. Other Bacteria as *Escherichia coli*, *Vibrio cholerae*, *Shigella dysenteriae* and *Salmonella typhi* etc. which indicating comparatively 'medium' intensity of 'sewerage pollution' and have a similar result with the present study.

The impact of 'sewerage pollution' on the variation of average DO concentration in **Dhanmondi, Ramna** and **Diabari Bottola** Lake found **'low'** from the present research. In Dhanmondi Lake, a study observed by (Shahjahan and Ahmed, 2016), the fecal coliform concentration of the lake was found 600 cfu/100 mL which indicating 'low' intensity of 'sewerage pollution' and have a similar result with the present study. In Ramna Lake, a study observed by (Sarker et al., 2019), the fecal coliform concentration of the lake was found 10 to 13 cfu/100 mL which indicating 'low' intensity of 'sewerage pollution' and have a similar result with the present study. In Diabari Bottola Lake, as there are very few studies have been done, therefore current status of fecal coliform concentration on 'sewerage pollution' could not found to cross check with the present research.

7.1.1.2 Water Pollution from Industrial Effluent

There are various industries and factories situated in and around Dhaka city. Maximum of those industries are located near to different water bodies areas that have been polluting the water frequently without any kind of treatment. For this external factor 'industrial pollution', 'Biochemical Oxygen Demand (BOD5) concentration' that specifies one of the indicators of 'industrial pollution' have been selected for the cross check with the present research results that identified from other studies. From the above (Table – 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8 and 7.9) and (Figure – 7.2 and 7.8), it appears that, the impact of 'industrial pollution' on the variation of average DO concentration in **Gulshan-Baridhara, Hatirjheel, Ashulia** and **Birulia** urban wetland found **'high'** from the present research.

In Gulshan-Baridhara Lake, a study conducted by (Nabila et al., 2022), the BOD5 concentration was found 25.43 to 25.70 mg/l, that indicates 'high' level of 'industrial pollution' which have a similar result with the present study. Another study conducted by (Sabit and Ali, 2015), the BOD5 concentration was found up to 46.0 mg/l, that indicates 'high' level of 'industrial pollution' which have a similar result with the present study.

In Hatirjheel Lake, a study conducted by (Nabila et al., 2022), the BOD5 concentration was found 26.10 to 26.50 mg/l, that indicates 'high' level of 'industrial pollution' which have a similar result with the present study. Another study was conducted by (Tariquzzaman et al., 2016), the BOD5 concentration was found 154 mg/l, that indicates 'high' level of 'industrial pollution' which have a similar result with the present study.

One study in Turag River investigated by (Aktar and Moonajilin, 2017), the BOD5 concentration was found 13 to 73 mg/l, that indicates 'high' level of 'industrial pollution' which have a similar result with the present study. As Ashulia and Birulia wetlands are the floodplain of Turag River, during monsoon when the water level rise at high level, the water normally flooded to Ashulia and Birulia wetlands and get polluted.

The impact of 'industrial pollution' on the variation of average DO concentration in **Dhanmondi, Ramna** and **Diabari Bottola** Lake found **'low'**. In Dhanmondi Lake, a study conducted by (Shahjahan and Ahmed, 2016), the BOD5 concentration was found lesser than 2.0 mg/l, that indicates 'low' level of 'industrial pollution' which have a similar result with the present study. Another study conducted by (Parvin et al., 2019), the BOD5 concentration was found lesser than 2.90 mg/l, that indicates 'low' level of 'industrial pollution' which have a similar result with the present study as well.

In Ramna Lake, a study observed by (Islam et al., 2015), the BOD5 concentration was found 0.93 mg/l, that indicates 'low' level of 'industrial pollution' which have a similar result with the present study. Another study observed by (Parvin et al., 2019), the BOD5 concentration was found 2.30 mg/l, that indicates 'low' level of 'industrial pollution' which have a similar result with the present study.

In Diabari Bottola Lake, a study observed by (Zaman et al., 2018), the BOD5 concentration was found 18.33 mg/l. This study also observed industrial and agricultural waste dumping at the site that were responsible for the BOD level. This indicates 'medium' level of 'industrial pollution' which do not have a similar result with the present study. Present study observed Turag River connection gate closed by relevant authorities that could pollute the water from industries.

7.1.1.3 Population Density

High population growth has a high impact on the water quality of an urban wetland. From the above (Table – 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8 and 7.9) and (Figure – 7.3), it appears that, the impact of 'population density' on the variation of average DO concentration in **Dhanmondi, Hatirjheel** and **Ramna** Lake found **'high'**; in **Gulshan-Baridhara** and **Diabari Bottola** Lake found **'medium'** and in **Ashulia** and **Birulia** urban wetland found **'low'**.

In Dhanmondi Lake, have been observed human induced municipal garbage waste and effluent, construction waste, bathing, washing activities by different user groups of people that indicating high impact of 'population density' on the variation of average DO concentration in the lake.

In Hatirjheel Lake, have been observed municipal garbage waste and effluent near the bank, lot of effluent outfalls, some construction waste, bathing, washing activities by floating people that indicating high impact of 'population density' on the variation of average DO concentration in the lake.

In Ramna Lake, have been observed low and negligible human induced activities as the existing management authorities are strictly maintaining the lake at present. So, this condition indicating low impact of 'population density' on the variation of average DO concentration in the lake though this area have a 'high' population density.

In Gulshan-Baridhara Lake, have been observed lot of municipal garbage waste and effluent, lot of effluent outfalls, construction waste and other activities by local people that indicating high impact of 'population density' on the variation of average DO concentration in the lake though this area have a 'medium' population density.

In Diabari Bottola Lake, have been observed agricultural activities with less harmful organic fertilizer (informed by stakeholder), some construction waste effluent that can be discharge by the metro rail construction yard that far from the water body, bathing, washing activities by local people with low human induced activities still now as the existing management authorities and fish farmers have been strictly maintaining the lake at present. So, this condition indicating low impact of 'population density' on the variation of average DO concentration in the lake though this area have a 'medium' population density.

In Ashulia urban wetland, have been observed lot of agricultural activities with high harmful chemical fertilizer and pesticides during winter season (informed by stakeholder), municipal garbage waste and effluent, construction waste near the bank and effluent disposal by different Private Land Development Companies (PLDC), waste from brick kilns yards, effluent from water vessels, bathing, washing activities by local people and other activities by local people that indicating high impact of human induced activities on the variation of average DO concentration in the lake though this area have a 'low' population density. Therefore, lack of awareness among people towards the water body conservation and use has high impact on DO concentration rather the low 'population density' in this urban wetland.

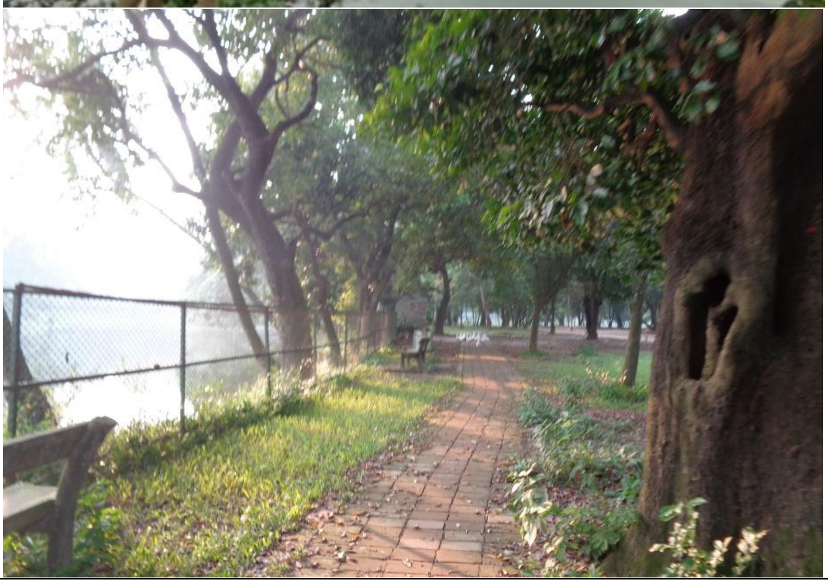
In Birulia urban wetland, have been observed lot of agricultural activities with high harmful chemical fertilizer and pesticides during winter season (informed by stakeholder), municipal garbage waste and effluent, construction waste near the bank, effluent from water vessels, bathing, washing activities by local people and other activities by local people that indicating high impact of human induced activities on the variation of average DO concentration in the lake though this area have a ‘low’ population density. Therefore, lack of awareness among people towards the water body conservation and use has high impact on DO concentration rather the low ‘population density’ in this urban wetland. According to a study, in the country of Ghana, in (2014), investigated that, increase of population exaggerate the reduction of the Dissolved Oxygen (DO) concentration in an urban water body, that indicate some similar and dissimilar result with the present study according to the condition of study areas.

7.1.1.4 Presence of Surrounding Shaded Trees and Vegetations

Presence of surrounding shaded trees and vegetations have a considerable effect on water quality of an urban wetland. From the above (Table – 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8 and 7.9) and (Figure – 7.4), it appears that, the impact of ‘presence of surrounding shaded trees and vegetations’ on the variation of average DO concentration in **Dhanmondi** and **Ramna** Lake found **‘high’**; in **Gulshan-Baridhara** and **Hatirjheel** Lake found **‘medium’**; in **Diabari Bottola**, **Ashulia** and **Birulia** urban wetland found **‘low’**. From the field photographs in (Table – 7.10), that reflected a clear picture on this issue.

Table – 7.10: Presence of shaded trees and vegetations surrounding the selected urban wetlands areas

Study area	External factor – 5: Presence of shaded trees and vegetations surrounding the selected urban wetlands areas
Study area – 1: Dhanmondi Lake	

Study area – 2: Gulshan-Baridhara Lake	
Study area – 3: Hatirjheel Lake	
Study area – 4: Ramna Lake	

Study area – 5: Diabari Bottola Lake	
Study area – 6: Ashulia urban wetland	
Study area – 7: Birulia urban wetland	

Level of influence	Indication
High	
Medium	
Low	

7.1.1.5 Air Pollution

Atmospheric pollution from anthropogenic and natural factors affects the water quality of an urban wetland frequently. Oxides of Sulphur (SO2) and Nitrogen (NO2), Green House Gases (GHGs), Carbon mono Oxide (CO), Particulate Matter (PM) etc. have a harmful effect on the quality of water. From the above (Table – 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8 and 7.9) and (Figure – 7.5), it appears that, the impact of ‘air pollution’ on the variation of average DO concentration in **Gulshan-Baridhara**, **Hatirjheel** and **Ashulia** urban wetland found **‘high’**; in **Dhanmondi** and **Birulia** urban wetland found **‘medium’**; in **Ramna** and **Diabari Bottola** Lake found **‘low’**.

7.1.1.6 Existing Wetland Management Structures

Relevant authorities have a high responsibility for sustainable management of a water body in any city. The impact of ‘existing wetland management structures’ on the variation of average DO concentration in **Ramna** and **Diabari Bottola** Lake found **‘high’**; in **Dhanmondi** Lake found **‘medium’**; in **Gulshan-Baridhara**, **Hatirjheel**, **Ashulia** and **Birulia** urban wetland found **‘low’** (Table – 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8 and 7.9) and (Figure – 7.6).

7.1.2 Policy and Management Plan Suggestions for Sustainable Urban Wetland Management

From the above results, this study recommended some policy and management plan suggestions for sustainable urban wetland management based on the lack of sustainability analysis as follows:

7.1.2.1 Study Area - 1: Dhanmondi Lake

In Dhanmondi Lake, the average Dissolved Oxygen (DO) concentration of **7.03 mg/l** is mainly caused by the external factors of population density (high), air pollution (medium) and existing wetland management structures (medium). Therefore, required sustainable policies and management plan on these factors need to be implemented.

7.1.2.2 Study Area - 2: Gulshan-Baridhara Lake

In Gulshan-Baridhara Lake, the average DO concentration of **3.03 mg/l** is mainly caused by water pollution from sewerage effluent (high), water pollution from industrial effluent (high), population density (medium), presence of surrounding shaded trees and vegetations (medium), air pollution (high) and existing wetland management structures (low). Therefore, required sustainable policies and management plan on these factors need to be implemented.

7.1.2.3 Study Area - 3: Hatirjheel Lake

In Hatirjheel Lake, the average DO concentration of **5.17 mg/l** is mainly caused by water pollution from sewerage effluent (high), water pollution from industrial effluent (high), population density (high), presence of surrounding shaded trees and vegetations (medium), air pollution (high) and existing wetland management structures (low). Therefore, required sustainable policies and management plan on these factors need to be implemented.

7.1.2.4 Study Area - 4: Ramna Lake

In Ramna Lake, the average DO concentration of **8.22 mg/l** is mainly caused by population density (high). Therefore, required sustainable policies and management plan on this factor need to be implemented.

7.1.2.5 Study Area - 5: Diabari Bottola Lake

In Diabari Bottola Lake, the average DO concentration of **6.77 mg/l** is mainly caused by population density (medium) and presence of surrounding shaded trees and vegetations (low). Therefore, required sustainable policies and management plan on these factors need to be implemented.

7.1.2.6 Study Area - 6: Ashulia Urban Wetland

In Ashulia urban wetland, the average DO concentration of **5.64 mg/l** is mainly caused by water pollution from sewerage effluent (medium), water pollution from industrial effluent (high), presence of surrounding shaded trees and vegetations (low), air pollution (high) and existing wetland management structures (low). Therefore, required sustainable policies and management plan on these factors need to be implemented.

7.1.2.7 Study Area - 7: Birulia Urban Wetland

In Birulia urban wetland, the average DO concentration of **5.12 mg/l** is mainly caused by water pollution from sewerage effluent (medium), water pollution from industrial effluent (high), presence of surrounding shaded trees and vegetations (low), air pollution (medium) and existing wetland management structures (low). Therefore, required sustainable policies and management plan on these factors need to be implemented.

Therefore, the study identified that, average DO concentration variation of maximum urban wetlands has been affected mainly by existing wetland management structures, water pollution from industrial effluent, population density, water pollution from sewerage effluent, air pollution and presence of surrounding shaded trees and vegetations in that order. So, proper sustainable policies and management plan on all these factors need to be implemented for the selected urban wetlands respectively. For an example, according to a doctoral dissertation research in Cleveland State University, (USA), conducted by (Huhnke, 2018), the important factors affecting minimum DO concentration in River water have been identified as municipal wastewater treatment plant effluent BOD, municipal wastewater treatment plant effluent discharge Q, River water discharge Q, River water temperature and municipal wastewater treatment plant effluent DO in that order. Therefore, there are variation of different external factors and their level of influence on the DO concentration of water bodies in different areas in the world. These can vary widely according to location, urban development criteria, geomorphological, hydrological, climatic variation in place to place depending on the anthropogenic and natural stresses on the urban wetlands.

From the overall results, (Table – 7.11) showing total number of external factors have been influencing the average DO concentration across selected urban wetlands as follows:

Table – 7.11: Total number of external factors influencing the variation of average DO concentration across selected urban wetlands

Study area	Average Dissolved Oxygen (DO) concentration (mg/l)	Lack of sustainability of external factors influencing the variation of average DO concentration across selected urban wetlands	Total number of external factors that affecting the variation of average DO concentration (nos.)
Study Area - 1: Dhanmondi Lake	7.03	Population density (high), air pollution (medium) and existing wetland management structures (medium)	3
Study Area - 2: Gulshan-Baridhara Lake	**3.03**	Water pollution from sewerage effluent (high), water pollution from industrial effluent (high), population density (medium), presence of surrounding shaded trees and vegetations (medium), air pollution (high) and existing wetland management structures (low)	**6**
Study Area - 3: Hatirjheel Lake	5.17	Water pollution from sewerage effluent (high), water pollution from industrial effluent (high), population density (high), presence of surrounding shaded trees and vegetations (medium), air pollution (high) and existing wetland management structures (low)	6
Study Area - 4: Ramna Lake	**8.22**	Population density (high)	**1**
Study Area - 5: Diabari Bottola Lake	6.77	Population density (medium) and presence of surrounding shaded trees and vegetations (low)	2
Study Area - 6: Ashulia Urban Wetland	5.64	Water pollution from sewerage effluent (medium), water pollution from industrial effluent (high), presence of surrounding shaded trees and vegetations (low), air pollution (high) and existing wetland management structures (low)	5
Study Area - 7: Birulia Urban Wetland	5.12	Water pollution from sewerage effluent (medium), water pollution from industrial effluent (high), presence of surrounding shaded trees and vegetations (low), air pollution (medium) and existing wetland management structures (low)	5

(Source: Author personal field observation)

From the above analysis, we can see that, if the number of total external factors are decreases (example as Study Area - 4: Ramna Lake; total external factors - **1 nos.**), then the average DO concentration across urban wetlands are increases (**8.22** mg/l) (Figure – 7.9). Another way, if the number of total external factors are increases (example as Study Area - 2: Gulshan-Baridhara Lake; total external factors - **6 nos.**), then the average DO concentration across urban wetlands are decreases (**3.03** mg/l) (Figure – 7.10). Therefore, there is a strong relation between the selected external factors and their influence with the average DO concentration variation across selected urban wetlands in this present research.

Lack of sustainability of external factors in Study area – 4: Ramna Lake

DO = 8.22 mg/l

Population density

Figure – 7.9: Lack of sustainability of external factors in Study area – 4: Ramna Lake (developed by the author)

Lack of sustainability of external factors in Study area – 2: Gulshan-Baridhara Lake

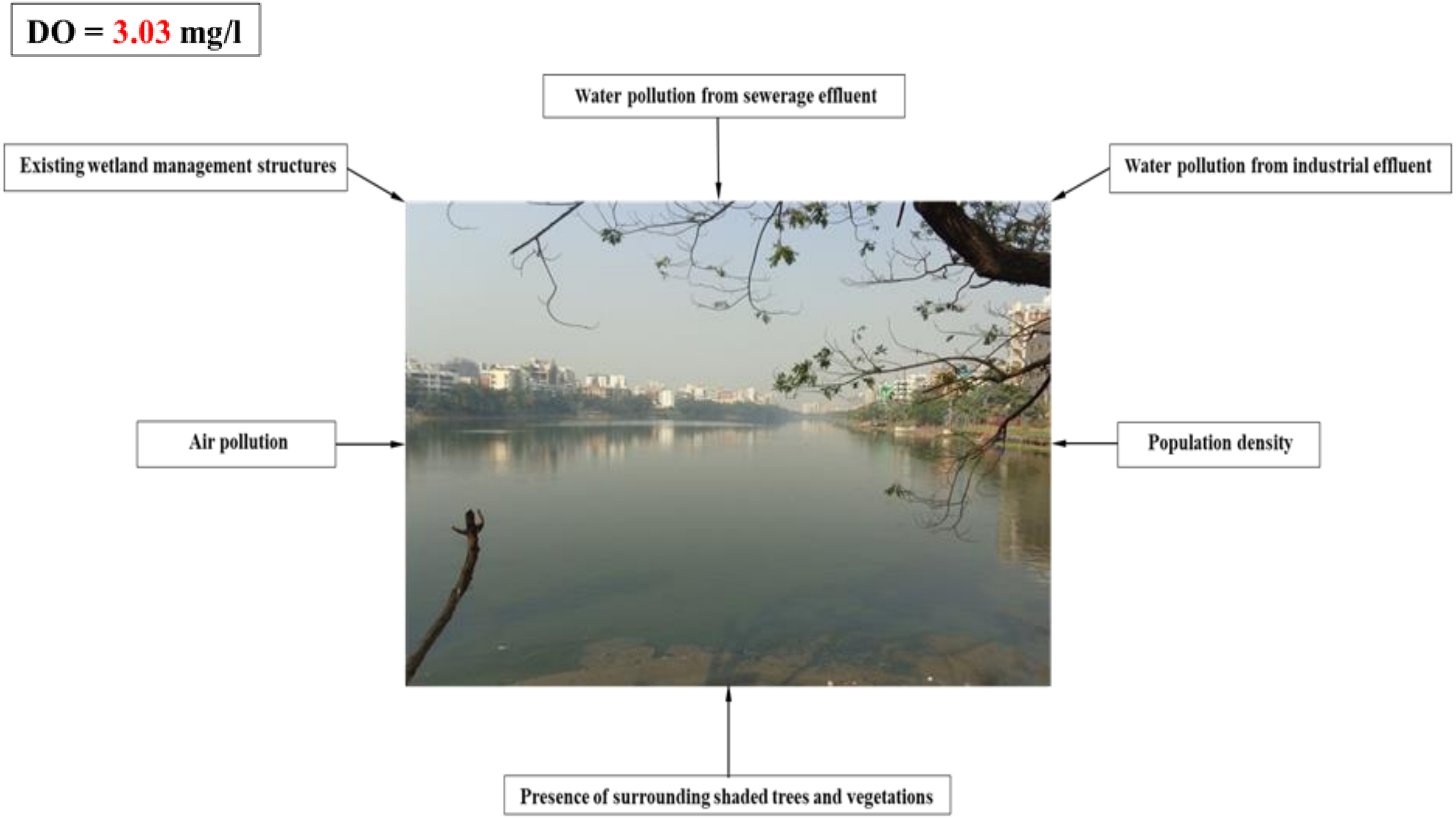


Figure – 7.10: Lack of sustainability of external factors in Study area – 2: Gulshan-Baridhara Lake (developed by the author)

7.2 Concluding Remarks

This chapter discussed the results of applicability of the ‘Urban Wetland Sustainability Framework (UWSF) Model – 2’ across study area context on sustainable conservation and management of selected urban wetlands.

CHAPTER – VIII

SUMMARY OF THE STUDY (CHAPTER - WISE)

This chapter discussed the overall summery of the research covering all finding and analysis chapters that discussed earlier. This section covers the summary of study area stakeholder perceptions, for institutional stakeholder expert's perceptions and author personal field observation of selected urban wetlands according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1', water quality assessment summary results, summary of author personal field observation according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 2' that followed by the first, second, third and fourth objectives and research questions of the study.

8.1 According to the Study Area Stakeholder Perceptions

This section deals with the summery of the study area stakeholder perceptions on current scenario, existing roles and challenges of the urban wetlands management and use according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' in seven study areas.

8.1.1 Current Scenario and Existing Role of Selected Urban Wetlands According to the Urban Wetland Sustainability Framework (UWSF) Model – 1 for Study Area Stakeholder Perceptions

(1) In the light of Attribute - 1: 'Contribution for biodiversity conservation and enhancement', it is found that the seven selected urban wetlands have been contributing different aquatic plant, fish, wildlife species, terrestrial trees, wildlife and bird species etc. Total five (5) species of aquatic plants, thirty-two (32) species of fishes, seven (7) species of aquatic wildlife species, thirty-eight (38) species of terrestrial trees, sixteen (16) species of terrestrial wildlife, nineteen (19) species of terrestrial birds from seven study areas have been living currently those identified by the stakeholder perceptions.

(2) IUCN based five freshwater taxonomic groups as decapods, fishes, mollusks, odonates, aquatic plants etc. that have most ecological roles has been identified by the stakeholder as well. Freshwater decapods as crabs (local name Kakra) have been disappeared in most of the selected urban wetlands and decreased than the past in some of urban wetlands as they preferred to live in good quality of water and freshwater shrimps (local name Chingri) identified almost absent in most of the selected urban wetlands from stakeholder perceptions.

(3) Freshwater fishes contributing different fish species have been declined than the past and have high risk of conservation status in most of the urban wetlands. Among all fish species, some fish species have been identified as reduced and some species identified as disappeared from some of the urban wetlands by the stakeholder. According to stakeholder, seasonal fluctuation of water depth (at least 4 to 5 feet increase of depth in monsoon) found in all selected urban wetlands that directly affecting the availability of species diversity, therefore, maximum availability of fishes found in monsoon than other seasons of the year for abundance of water.

(4) Freshwater mollusks as snails and bivalves (local name Shamuk and Jhinuk) still have high conservation significance in most of the selected urban wetlands, but declined than the past in some of the urban wetlands.

(5) Freshwater odonates as dragonflies (local name Foring) decreased than the past in most of the selected urban wetlands.

(6) Freshwater based some of floating aquatic plant species presence have been identified in most of the urban wetlands by the stakeholder, among them alien invasive plant species as water hyacinth (local name Kochuripana) have been invading from long time in most of the urban wetlands and it took much challenges for cleaning and adding extra cost of labors for the local fishermen. There is few information found about the presence of bed level aquatic plant species for lack of stakeholder perceptions and knowledge.

(7) Water dependent birds still have high conservation significance surrounding most of the urban wetlands, but declined than the past in some of the urban wetland's areas.

(8) Stakeholder perceptions according to scale of contribution that reflected current status is also identified for biodiversity conservation and enhancement. From the perceptions it's identified that biodiversity of most fresh water wetlands has been declined than the past and the risk of local species has been increasing with time.

(9) According to the perceptions of stakeholder, this chapter identified that these seven water bodies are how much effective to handle the local and regional climate change impacts, heating and cooling impact in connection to Attribute - 2: 'Resilience of urban water bodies to face the challenge of climate change impacts. Resilience capacity for 'cooling effect during summer on heat stress of selected urban wetlands' identified as 'effective resilience' in maximum urban wetlands areas but has been reducing in some of urban wetland's areas in day time mainly during summer season than the past according to stakeholder. Water 'storage capacity during heavy rainfall on flood stress of selected urban wetlands' is identified for flood impact as well. According to perceptions, most of these selected urban wetlands is effective for storage of surrounding water during heavy rainfall still now that reflect an 'effective resilience' role on local climate change impacts as well.

(10) Community livelihood activities that satisfied Attribute - 3: 'Contribution for community livelihood' in selected seven wetlands have great economic scope in ensuring livelihood security of surroundings local people. Total sixteen (16) types of community livelihood activities and their scale of contribution have been identified during monsoon and winter seasons from seven study areas by the stakeholder perceptions that discussed as well.

(11) According to stakeholder perceptions, total ten (10) types of fishes identified relevant for commercial fishing-based livelihood (lease system) activities from seven urban wetlands, six (6) types of fishes identified relevant for angling/sport fishing activities and twelve (12) types of fishes identified relevant for livelihood activities based on natural water fishes (mainly study area - 6 and 7). Total fifteen (15) types of crops and vegetables are identified relevant for agricultural livelihood activities from some study areas (mainly study area - 5, 6 and 7).

(12) Existing and potential livelihood activities that reflected direct (wetland resource dependent) and indirect livelihood activities and their economic values in selected seven wetlands have been identified from stakeholder perceptions also. From seven study areas, direct livelihood has been contributing as commercial fish cultivation activities with yearly net income around 4 to 13 lacs taka (approx.) for one lease holder in some urban wetland's areas; contributing angling (sports/recreational fishing) activities with negligible income in some study areas and contributing fishing activities with yearly net income around 50 to 80 thousand taka (approx.) for one fisherman in some urban wetlands areas.

(13) Direct livelihood has been contributing as agricultural activities for paddy cultivation with yearly net income for 1 bigha land around 20 thousand to 4 lacs taka (approx.) for one farmer or one lease holder in some urban wetlands areas; for tomato cultivation with yearly net income around 80 thousands to 1 lacs taka (approx.) for one lease holder; for other vegetables cultivation with yearly net income around 50 to 60 thousand taka (approx.) for one lease holder in some urban wetlands areas respectively.

(14) Direct livelihood has been contributing as water transport activities from water buses with yearly net income around 9 to 11 crore taka (approx.) for lease holder companies and yearly net income around 90 thousand to more than 3 lacs taka (approx.) for one boat master or one boatman in some urban wetlands areas.

(15) Direct livelihood has been contributing as paddle boating activities for recreation with yearly net income around 36.5 lacs taka (approx.) for lease holder companies, yearly net income around 9 lacs taka (approx.) for one paddle boatman and yearly net income around 3 lacs taka (approx.) for non-engine one boatman in some urban wetland's areas for recreation.

(16) Direct livelihood has been contributing as poultry activities (duck farming) with yearly net income around 60 to 70 thousand taka (approx.) for one poultry farmer in some urban wetlands areas.

(17) Contributing direct livelihood as brick manufacturing activities with yearly net income around 20 to 25 lacs taka (approx.) for one brick klin and yearly net income around 1 lacs taka (approx.) for one worker in some urban wetland's areas.

(18) Indirect livelihood has been contributing as big permanent restaurant activities with yearly net income around 6 lacs to 1 crore 27 lacs (approx.) taka for lease holder companies and small temporary restaurant activities with yearly net income around 7 to 55 lacs taka (approx.) for lease holder companies in some urban wetland's areas.

(19) Indirect livelihood has been contributing nursery activity with yearly net income around 1.5 to 2 lacs taka (approx.) for one nursery; easy bike activity with yearly net income around 3 lacs taka (approx.) for one driver; horse cart activity with yearly net income around 2 to 3 lacs taka (approx.) for one driver in some urban wetland's areas.

(20) Indirect livelihood has been contributing small shop for tea/cigarette around 1.4 to 5.4 lacs taka (approx.) in some urban wetlands' areas.

(21) Indirect livelihood has been contributing vendor activities by different professions with yearly net income around 72 thousand to 5.4 lacs taka (approx.) (200 to 1500 taka/day) for one vendor in selected urban wetland areas. Total thirty (30) types of vendors have been identified with various professions by stakeholder perceptions from seven study areas.

(22) Indirect livelihood has been contributing cleaning and washing the lake surrounding areas with yearly net income around 48 thousand to 2 lacs taka (approx.) for one worker and contributing security activities of lake surrounding areas with yearly net income about around 1.5 lacs taka (approx.) for one security man in some urban wetlands' areas.

(23) Wetland resource dependent main livelihood as fishing activities contributing around 12 to 13 lacs taka/year (approx.) from one urban water body (for study area - 6), but for data limitations it can not be identified for all urban wetlands.

(24) Identified that maximum urban wetlands have been contributing less wetland resource dependent livelihood for restrictions and currently minimal use of these livelihood by local community poor people. Local community poor people only have some indirect livelihood access. On the other way, there is a considerable scope for this direct livelihood activities in some urban wetlands (as study area - 6 and 7) by local village people who have access on it (as land owners, lease holders etc.), if proper conservation action will be taken in the future.

(25) Declining status of water quality directly affecting the biodiversity of most of the selected urban wetlands according to stakeholder. Wetland based main resource as fish species has been degrading that affecting directly on fishing-based direct livelihood with less economic profit than the past. Agricultural livelihood activity also hampered with low production status of crops than the past with moderate economic value for the same reason in some study areas.

(26) Identified about the stakeholder knowledge of legal acts and planning policies regarding the protection of wetlands in Dhaka city according to Attribute - 4: ‘Adequacy of the policy regime’. From the perceptions it’s identified that most of the respondent do not have any knowledge about policies and adequacy of policy regime.

(27) All public organizations that are directly involved to ensure protection of wetlands in Dhaka city, stakeholder perceptions and their scale of contribution have been identified to satisfy Attribute - 5: ‘Local acceptance and credibility of the role of relevant institutions’. Total ten (10) main relevant institutions and their role have been identified from seven study areas by the stakeholder perceptions, these are DSCC/DNCC, DWASA, DoE, Fisheries Department, Local Government Institutions (LGI), Mothsho Club, RAJUK, Bangladesh Army, PWD, Union Parishad (UP) etc.

(28) Stakeholder think that, DSCC performing with ‘effective contribution’ (for Study area - 1: Dhanmondi Lake) as good maintenance of lake and surrounding area; created good environment for the public use; authorities allow various professions to do their livelihood activities in the lake areas safely; authority every day cleans the lake and lake surrounding area in early morning; much staffs appointed from DSCC for working in this lake area that enhance livelihood of many people etc. Bangladesh Army performing with ‘effective contribution’ (for Study area - 3: Hatirjheel Lake) as strict maintenance, monitoring and implementation; trying to do their relevant works much effectively; good beautification of the lake area etc. PWD with ‘effective contribution’ (for Study area - 4: Ramna Lake) as effective maintenance of lake and park beautification and improvement; have been taken good steps on angling activities; proper maintenance by the relevant authorities for pollution control; have been taken good steps on water quality improvement etc. RAJUK, LGI performing with ‘effective contribution’ (for Study area - 5: Diabari Bottola Lake) respectively area basis as effective maintenance of water pollution; effective development of lake and lake side areas; allow various professions to do their livelihood activities in the lake areas; will develop more in future etc. and UP with ‘less effective contribution’ (for Study area - 6 and 7: Ashulia and Birulia urban wetlands) of acceptance and credibility as UP have very limited capacity and responsibility on conservation and management issue, maximum land is local people’s private land or leased land etc.

8.1.2 Challenges of Selected Urban Wetland Management and Use According to the Urban Wetland Sustainability Framework (UWSF) Model – 1 for Study Area Stakeholder Perceptions

(1) Main challenges of urban wetland management and use for Attribute - 1: ‘Contribution for biodiversity conservation and enhancement’, that identified from study area stakeholder perceptions as bad water quality by pollution through human interventions (by serious uncontrolled waste material and waste water pollution, inadequate sewerage connection and others) and natural activities (storm and rain water accumulation and mixed with surrounding harmful waste, waste water and finally store in the wetlands), urban development and encroachment etc.

(2) For Attribute - 2: ‘Resilience of urban water bodies to face the challenge of climate change impacts’, challenges of urban wetland management and use on ‘cooling effect during summer on heat stress of selected urban wetlands’ are generation of heat in day time presently, presence of less quantities of big shaded trees surrounding some of the water bodies areas, water almost dried for six months in some study areas etc. and challenges for ‘storage capacity during heavy rainfall on flood stress of selected urban wetlands’ are improper drainage connection in some areas that causing water logging sometimes etc.

(3) For Attribute - 3: ‘Contribution for community livelihood’, main challenges of urban wetland management and use on contribution for community livelihood that identified from study area stakeholder perceptions as lot of livelihood restrictions on the urban context, bad water quality, bad smell of water in winter season, using of cultivated fishes for the lack of natural water fishes, use of external medicine for purify bad water, need to provide costly additional fish food and fish lings often in the water body, absence of commercial lease system on fishing in some urban wetlands, less income and economic return than the past, less economic dependency of wetland resource based livelihood, lack of financial support from Government organizations for fish and agricultural resource improvement and development, less presence of visitors, lack of security and safety in some areas, presence of some unexpected people in the lake areas etc.

(4) For Attribute - 4: ‘Adequacy of the policy regime’, lack of awareness on policies and adequacy of policy regime among study area stakeholders are the main challenges identified.

(5) For Attribute - 5: ‘Local acceptance and credibility of the role of relevant institutions’, main challenges of urban wetland management and use on the role of relevant institutions are lack of maintenance on pollution and water quality improvement, less Government support for water quality improvement, less Government support for fish resource improvement and development, lack of security and safety in some areas, lack of manpower for maintenance and security etc.

8.2 According to Institutional Stakeholder Expert's Perceptions

This section discussed the summery of institutional stakeholder expert's perceptions on current scenario, existing roles and challenges of the urban wetlands management and use according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1' in seven study areas.

8.2.1 Current Scenario and Existing Role of Selected Urban Wetlands According to the Urban Wetland Sustainability Framework (UWSF) Model – 1 for Institutional Stakeholder Expert's Perceptions

(1) For Attribute - 1: 'Contribution for biodiversity conservation and enhancement', maximum stakeholders think that most of these selected urban wetlands have been in a serious threat with very low biodiversity (has been losing seriously) that performing 'less effective contribution'.

(2) For Attribute - 2: 'Resilience of urban wetlands to face the challenge of climate change impacts', maximum stakeholders think that most of these urban wetlands have been performing 'less effective resilience' for the 'cooling effect' and for 'storage capacity during heavy rainfall', maximum stakeholders think that most of these urban wetlands have been performing 'less effective resilience' to face the challenge of climate change impacts.

(3) For Attribute - 3: 'Contribution for community livelihood', maximum stakeholders think that most of these urban wetlands have been in a threat and in a very critical state presently that performing 'less effective contribution' on community livelihood.

(4) For Attribute - 4: 'Adequacy of the policy regime', different acts and rules according to stakeholders are as Town Improvement Act; Open space and water body conservation Act, 2000; Park, wetland and open spaces conservation Act, 2002; Environment conservation rules, 1995-2010; National Environment Policy, 2018; The Bangladesh Environment Conservation Act, 1995; The Bangladesh Environment Conservation Rules, 1997; National Biodiversity Assessment and Programme of Action 2020, 2014; The Bangladesh Climate Change Strategy and Action Plan (BCCSAP), 2009; The Brick Burning (Control) (Amendment) Act, 2001; Ozone Depleting Substances (Control) Rules, 2004; different Government National water rules and laws in different years; Joladhar Songrokkon Ain; Acts - yr.2000; Rules - yr.2005; Water law; Environment laws; Jolmohol policy, Water policies; Water acts etc. has been working on these urban wetlands.

(5) For Attribute - 4, maximum stakeholders think that, there are enough Government policies, rules, regulations, laws etc. are available in Bangladesh for the management of urban wetlands. These policies are adequate and effective.

(6) For Attribute - 5: 'Local acceptance and credibility of the role of relevant institutions', total twenty (20) relevant institutions and their role are extracted from stakeholders perceptions, these are RAJUK, PWD, DoE, DSCC/DNCC, Department of Fisheries (DoF), BFDC, DWASA, BWDB, BIWTA, BIWTC, Nodi Rokkha Commission, Bangladesh Army, Local Government Institutions (LGIs), Union Parishad-Ashulia/Birulia, CEGIS, SPARSO, Civil Society Organizations and NGOs as BAPA, BELA and POBA and Social Media etc.

(7) On Attribute - 5, maximum stakeholders think that, RAJUK, PWD, DoE, DSCC/DNCC, Department of Fisheries (DoF), BFDC, DWASA, BWDB, BIWTA, BIWTC, Nodi Rokkha Commission, Local Government Institutions (LGIs), CEGIS, SPARSO, Civil Society Organizations and NGOs as BAPA, BELA and POBA and Social Media are performing with 'moderately effective contribution' of acceptance and credibility respectively as these organizations may be trying to do their best, but output cannot reach in level; lack of coordination among all relevant organizations to handle every work on development; lack of management by relevant authorities; lack of manpower on maintenance issues still now etc. Bangladesh Army with 'effective contribution' of acceptance and credibility (on Hatirjheel management mainly) as performing good management and maintenance and Union Parishad (UP) (for Ashulia/Birulia) with 'less effective contribution' of acceptance and credibility as UP cannot doing any direct work on water body conservation; UP has very limited power to solve different problems connecting water bodies; there are neither NGOs nor environment departments are working on these water bodies; UP cannot tackle all pollution connecting water bodies etc.

8.2.2 Challenges of Selected Urban Wetland Management and Use According to the Urban Wetland Sustainability Framework (UWSF) Model – 1 for Institutional Stakeholder Expert's Perceptions

(1) For Attribute - 1: 'Contribution for biodiversity conservation and enhancement', main challenges of urban wetland management and use are identified as wetlands water quality degradation through human activities and by natural interventions, interrupting species diversity and ecological function of urban wetlands, destruction of habitat, affecting wetland species existence, endangered of wetland species day by day, fish mortality, affecting ideal water body criteria, interrupting natural drainage function and natural cleansing system of urban wetlands, failing the standard limit of maximum water quality parameters, lack of community involvement for biodiversity conservation, lack of awareness among public, endangering human health, unplanned urban development, unplanned land use, reduction of water retention areas by encroachment, over population pressure etc.

(2) For Attribute - 2: 'Resilience of urban water bodies to face the challenge of climate change impacts', main challenges of urban wetland management and use on 'cooling effect' are increase of over paved area in the city, increase of daily temperatures in the city day by day, raising the urban heat island effects, reduction of heat resistance capacity of these urban wetlands, serious air pollution, Particulate Matter (PM) deposition in the atmosphere, affecting human health and quality of urban life, lack of trees in water bodies areas, unplanned urban development, shrinkages of water areas etc.

(3) For Attribute - 2, main challenges of urban wetland management and use on 'storage capacity during heavy rainfall' are unplanned urban development, losing internal connectivity of these water bodies, encroachment and filling by land grabbers, narrowing of water courses, reduction of water retention capacity, reduction of sustainable capacity of urban wetlands, siltation, reduction of water holding capacity, reduction of water depth, interrupting natural drainage system, overloading of drainage systems, less capacity of drainage system, water logging, hampering functioning of main hydrological role for climate change impacts etc.

(4) For Attribute - 3: 'Contribution for community livelihood', main challenges of urban wetland management and use are identified as lot of restrictions for livelihood activities in urban context, limited access of tourism-based livelihood, less dependency on urban wetlands livelihood, uncontrolled pollution, less availability of wetland fishes, negligible consumption of urban wetlands fishes, negligible economic profit from urban wetland resource-based livelihood, interrupting fishing and agriculture-based livelihood, degradation of cultivated crops and fish quality for wetland bad water quality, reduction of crops yield, severe fish mortality, agricultural development, unplanned urban development, encroachment etc.

(5) For Attribute - 4: 'Adequacy of the policy regime', main challenges of urban wetland management and use on policy regime are lack of proper implementation/enforcement of policies still now exists in water sectors for sustainable management, lack of awareness on policies, lack of management, lack of coordination among authorities, lack of political commitment, rules are respectively less, need to be improving more, lack of implementation of rules, lot of gaps between laws and strict enforcement, lack of following policies in effective way by different organization and peoples who are responsible for these urban water bodies, lack of following connecting laws actually on Ashulia and Birulia water bodies, lack of following properly Acts - Yr.2000 and rules - Yr.2005 along with Water law and Environment laws, over population is the main hindrance for the management of these urban wetlands in and around Dhaka city, lack of systems, overlooking ‘Joladhar Songrokkon Aine’ on maximum urban wetland management issues etc.

(6) For Attribute - 5: ‘Local acceptance and credibility of the role of relevant institutions’, main challenges of urban wetland management and use on the role of relevant institutions are lack of awareness on valuation of water bodies, lack of coordination among all relevant organizations, lack of maintenance and management by relevant authorities, lack of community involvement and empowerment, lack of adequate secondary transfer stations for disposal of solid waste in the city, lack of manpower on maintenance issues, lack on water connecting planning by the higher authorities from the beginning in Dhaka city, lack of integrated water resource based management, lack of adequate pollution measures by implementation of policies, lack of local level management etc.

8.3 According to Author Personal Field Observation

This section discussed the summery of author personal field observation on current scenario, existing roles and challenges of the urban wetlands management and use according to the ‘Urban Wetland Sustainability Framework (UWSF) Model – 1’ in seven study areas.

8.3.1 Current Scenario and Existing Role of Selected Urban Wetlands According to the Urban Wetland Sustainability Framework (UWSF) Model – 1 for Author Personal Field Observation

(1) From field observation in seven study areas, on Attribute - 1: ‘Biodiversity conservation and enhancement’, total seven (7) species of aquatic plants, ten (10) species of fishes, five (5) species of aquatic wildlife, thirty-four (34) species of terrestrial trees, eleven (11) species of terrestrial wildlife, eleven (11) species of terrestrial birds have seen.

(2) It’s observed that, biodiversity of these selected maximum fresh water wetlands is in a serious risk and ecological health and habitat has been degrading severely.

(3) For Attribute - 2: ‘Resilience of urban water bodies to face the challenge of climate change impacts’, most of these selected urban wetlands for ‘cooling effect’ observed ‘moderately effective resilience’; for ‘storage capacity’ of urban wetlands observed ‘moderately effective to effective resilience’; for ‘drought stress’, these water bodies have been observed ‘less effective resilience’ and most of the urban wetlands observed a serious threat on ‘water quality’.

(4) For Attribute - 3: ‘Contribution of community livelihood’ observed in a risk with ‘less to moderately effective contribution’ in most of the study areas.

(5) From observation, it was identified that, biodiversity, climate change impacts and community livelihood are interconnected to each other. For climate change impacts and other challenges, ongoing decline in freshwater biodiversity (mainly fishes) has been seriously impacting on fishing-based livelihood activities and agricultural-based livelihood activities also hampering for polluted water than the past in most of the selected urban wetlands.

(6) For Attribute - 4: ‘Adequacy of the policy regime’, from the literature review we saw that, there are a lot of existing policies, laws, acts, regulations, strategies which have been developed by the Bangladesh Government on the wetland sectors in the country. But, on the urban wetland sectors, there are still lack of proper sustainable policies on different factors with inconducive in nature. Another way, there is a huge gap between existing policies and implementation of policies that have been unsustainable for appropriate urban wetland management still now. Therefore, there is urgent need to think about urban wetland management in the capital with sustainable policies and their proper implementations for the long-term economic development in the country.

(7) For Attribute - 5: ‘Local acceptance and credibility of the role of relevant institutions’, all relevant organizations have been trying to do their works on this issue, but still there are lot of problems exist connecting these urban wetland management.

8.3.2 Challenges of Selected Urban Wetland Management and Use According to the Urban Wetland Sustainability Framework (UWSF) Model – 1 for Author Personal Field Observation

(1) For Attribute - 1: 'Contribution for biodiversity conservation and enhancement', main challenges of urban wetland management and use identified as bad water quality by pollution through human and natural activities, seasonal difference of water level interrupting biodiversity, fish mortality, unplanned urban development, unplanned land use, encroachment, rapid population pressure, climate change impacts, less importance has been giving on the value of biodiversity and ecosystem conservation, less awareness on conservation, lack of community and stakeholder involvement on conservation and management, degradation of ground water ecology etc.

(2) For Attribute - 2: 'Resilience of urban water bodies to face the challenge of climate change impacts', challenges of urban wetland management and use observed on 'cooling effect' are as increase of over paved concrete areas in the city that are producing heat, urban development, atmospheric temperature getting high day by day, heat absorbing capacity of wetlands are reducing for filling and encroachment of wetland areas, siltation, destroying aquatic ecosystems by decreasing Dissolved Oxygen (DO), depletion of species, habitat loss and degradation etc.

(3) For Attribute - 2, challenges observed on 'storage capacity' are as urban development, unplanned land use, filling and encroachment of wetland areas, insufficient capacity of water bodies to store water, siltation, bed level reduction of water bodies through accumulation of sludge, lack of proper functioning of drainage infrastructures, improper drainage connection and capacity etc.

(4) For Attribute - 2, challenges observed on 'drought stress' are as lower water level in winter and summer season, threat for aquatic vegetation, fishes, wildlife and other species, reduction of ground water availability in the warm summer season, risk of earthquake etc.

(5) For Attribute - 2, challenges observed on 'water quality' are as high pollution load during high intensity of precipitation by climate change impacts.

(6) For Attribute - 3: 'Contribution for community livelihood', challenges observed as livelihood restrictions on the urban context, less scope on wetland resource dependent livelihood for local poor community people, most demanded local fresh water fishes have been replaced by culture and less demanded fish species for water quality degradation, pollution, urbanization and climate change impacts etc.

(7) For Attribute - 4: 'Adequacy of the policy regime', challenges observed are as lack of enforcement of policies, laws, regulations on source pollution and water quality improvement, lack of implementation of laws on public pollution of lake water by throwing wastes, lack of enforcement of policies on surrounding domestic, construction, sewerage, industrial and other urban waste pollution, encroachment of urban wetlands should be stopped by the proper laws as 'Joladhar Songrokkon Ain' and others, lack of implementation of policies on security and safety functions, lack of enforcement of policies on presence of unexpected people sometimes in the study areas.

(8) For Attribute - 5: 'Local acceptance and credibility of the role of relevant institutions', some challenges observed as lack of sustainable conservation, maintenance and management of urban wetlands, lack of stakeholder perceptions on management, lack of community people involvement on planning, conservation and management, lack of proper waste management, lack of thinking of wetland connecting values and services, lack of coordination among all relevant organizations, lack of proper maintenance of existing drainage connections, lack of management on water quality improvement, pollution etc., lack of management on surrounding domestic, construction, sewerage, industrial and other urban waste pollution control, lack of management on awareness about environmental conservation and management by the public and relevant authorities, lack of management on security function, in some urban wetlands' areas, there is no contribution on conservation and management at all, limited resources and power to handle all wetland connecting issues, lack of management from higher Government authorities towards conservation of the urban wetland etc.

8.4 Summary of the Water Quality Assessment

This section entails the summary of the water quality assessment of different parameters that conducted in seven selected urban wetlands.

(1) Water temperature: From the overall results it was revealed that, the water temperature values of all selected water bodies were within the EQS limit for aquatic biodiversity conservation and lowest temperature was recorded in December and the highest was recorded in November at all sample locations of selected urban wetlands.

(2) pH: From the overall results it was revealed that, pH values were within the EQS limit for aquatic biodiversity conservation of all selected urban wetlands.

(3) DO: [3a] From the overall results it was revealed that, there were monthly variation among DO values of selected all urban wetlands. Among all selected urban wetlands, DO values of both sample locations in three tested months of Study area - 4: Ramna Lake urban water body (6.70 to 10.90 mg/L) were within the EQS limit that indicated good water quality for aquatic biodiversity conservation.

(3b) DO values in Bottola Dia Bari Lake (10.20 mg/L - sample location 02, in December), Dhanmondi Lake (10.0 mg/L - sample location 02, in November); Hatirjheel Lake (9.80 mg/L - sample location 02, in December); Birulia (8.00 mg/L - sample location 01, in October); Ashulia (7.50 mg/L - sample location 01, in October); Gulshan-Baridhara Lake (6.10 mg/L - sample location 01, in October) water bodies showed within the EQS limit that indicated good water quality for aquatic biodiversity conservation.

(3c) DO values in Birulia water body (1.80 mg/L - sample location 01, in December), Bottola Dia Bari Lake (2.60 mg/L - sample location 02, in November), Ashulia water body (3.30 mg/L - sample location 02, in December), and Dhanmondi Lake (3.80 mg/L - sample location 01, in December) water bodies showed not within the EQS limit that indicated bad water quality for aquatic biodiversity conservation.

(3d) DO values in Gulshan-Baridhara (almost 0.0 mg/L - sample location 02, in November) and Hatirjheel (almost 0.0 mg/L - sample location 02, in November) water body showed not within the EQS limit that indicated worst water quality for aquatic biodiversity conservation.

(3e) Therefore it can be said that Study area - 4: Ramna Lake water quality is the ‘best’ among other selected water bodies on DO results; Study area - 2: Gulshan-Baridhara and Study area - 3: Hatirjheel Lake showed ‘worst’ in water quality than other selected urban wetlands on DO results.

(4) BOD_5: (4a) From the overall results it was revealed that, there were monthly variation among BOD5 values of selected all urban wetlands.

(4b) BOD5 values in Dhanmondi Lake (6.00 mg/L - sample location 02, in November), in Ramna Lake (3.00 mg/L - sample location 02, in November), in Bottola Dia Bari Lake (3.00 mg/L - sample location 01 & 02, in October and November), in Ashulia (2.00 mg/L - sample location 01 & 02, in December), in Birulia (3.00 mg/L - sample location 02, in November) urban water bodies showed within the EQS limit that indicated comparatively good water quality for aquatic biodiversity conservation.

(4c) BOD5 values in Dhanmondi Lake (13.0 mg/L - sample location 01, in November), in Ramna Lake (12.0 mg/L - sample location 01, in November), in Bottola Dia Bari Lake (14.0 mg/L - sample location 01 & 02, in December), in Ashulia (12.0 mg/L - sample location 01, in November), in Birulia (20.0 mg/L - sample location 02, in December) urban water bodies showed not within the EQS limit that indicated bad water quality for aquatic biodiversity conservation.

(4d) BOD5 values in Gulshan-Baridhara Lake (23.00 mg/L - sample location 02, in November) and (23.00 mg/L - sample location 01 & 02 in December), in Hatirjheel Lake (10.00 mg/L - sample location 02, in November) and (46.0 mg/L - sample location 01, in October) urban water body showed not within the EQS limit that indicated worst water quality for aquatic biodiversity conservation.

(5) COD: From the overall results it was revealed that, there were monthly variation among COD values of selected all urban wetlands. COD values of both sample locations in three tested months among all selected urban wetlands were within the EQS limit that indicated good water quality for aquatic biodiversity conservation.

(6) Turbidity: (6a) From the overall results it was revealed that, there were monthly variation among Turbidity values of selected all urban wetlands.

(6b) Turbidity values in Dhanmondi Lake (4.91 mg/L - sample location 01, in October), in Ramna Lake (5.70 mg/L - sample location 01, in October), in Ashulia (7.28 mg/L - sample location 01, in October) urban wetlands showed within the EQS limit that indicated comparatively good water quality for aquatic biodiversity conservation.

(6c) Turbidity values in Dhanmondi Lake (32.40 mg/L - sample location 02, in November), in Ramna Lake (12.0 mg/L - sample location 01, in November), in Ramna Lake (18.70 mg/L - sample location 01, in November), in Ashulia (63.20 mg/L - sample location 02, in November), urban wetlands showed not within the EQS limit that indicated bad water quality for aquatic biodiversity conservation.

(6d) Turbidity values in Gulshan-Baridhara, Hatirjheel, Bottola Dia Bari Lake and Birulia urban wetlands in both sample locations showed not within the EQS limit that indicated worst water quality for aquatic biodiversity conservation.

(7) NO3-N: From the overall results it was found that, there were monthly variation among NO3-N values of selected all urban wetlands. NO3-N values of both sample locations in three tested months among all selected urban wetlands were within the EQS limit that indicated good water quality for aquatic biodiversity conservation.

(8) PO4: [8a] From the overall results it was revealed that, there were monthly variation among PO4 values of selected all urban wetlands.

(8b) PO4 values in Dhanmondi Lake (1.20 & 5.10 mg/L - sample location 02 & 01, in November & October), in Gulshan-Baridhara Lake (0.70 mg/L - sample location 02, in November), in Ramna Lake (0.10 & 4.90 mg/L - sample location 01 & 02, in October & December), in Bottola Dia Bari Lake (3.00 mg/L - sample location 01, in November), in Ashulia (0.00 & 5.70 mg/L - sample location 01 & 02, in November & December), in Birulia

(0.30 mg/L - sample location 01, in November) urban wetlands showed within the EQS limit that indicated comparatively good water quality for aquatic biodiversity conservation.

(8c) PO4 values in Gulshan-Baridhara Lake (8.70 mg/L - sample location 02, in October), in Hatirjheel Lake (8.00 & 18.10 mg/L - sample location 01, in December & October), in Bottola Dia Bari Lake (7.60 mg/L - sample location 01, in October), in Birulia (6.50 mg/L - sample location 02, in December) urban wetlands showed not within the EQS limit that indicated comparatively bad water quality for aquatic biodiversity conservation.

(9) TDS: From the overall results it was revealed that, there were monthly variation among TDS values of selected all urban wetlands. TDS values of both sample locations in three tested months among all selected urban wetlands were within the EQS limit that indicated good water quality for aquatic biodiversity conservation.

(10) EC: From the overall results it was revealed that, there were monthly variation among EC values of selected all urban wetlands. EC values of both sample locations in three tested months among all selected urban wetlands were within the EQS limit that indicated good water quality for aquatic biodiversity conservation.

(11) It was identified that, Temperature, pH, Chemical Oxygen Demand (COD), Nitrate-Nitrogen (NO_3-N), Total Dissolved Solid (TDS), Electrical Conductivity (EC) etc. are within the permissible limit of Environmental Quality Standard (EQS) that has been followed by the DoE and Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), Turbidity, Phosphate (PO_4) are not within the permissible limit of (EQS) for most of the urban wetlands.

(12) Therefore, the results revealed that, the water quality parameters of the selected study areas are highly dominated by anthropogenic and natural activities and in a serious risk for aquatic biodiversity conservation in maximum selected wetlands in the capital.

8.5 Summary of the Applicability of the Urban Wetland Sustainability Framework (UWSF) Model – 2 Across Study Area Context

This section discussed the summery of the external factors and how these factors affecting the variation of Dissolved Oxygen (DO) concentration across study area by the author personal field observation according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 2' that already discussed in Chapter - II and III to get a picture on sustainable urban wetlands management based on the water quality in seven study areas. The study identified that, average DO concentration variation of maximum urban wetlands has been affected mainly by existing wetland management structures, water pollution from industrial effluent, population density, water pollution from sewerage effluent, air pollution and presence of surrounding shaded trees and vegetations in that order. So, proper sustainable policies and management plan on all these factors need to be implemented for the selected urban wetlands respectively. From the analysis, this study showed that, if the number of total external factors are decreases then the average DO concentration across urban wetlands are increases. Another way, if the number of total external factors are increases, then the average DO concentration across urban wetlands are decreases. Therefore, there is a strong relation between the selected external factors and their influence with the average DO concentration variation across selected urban wetlands in this present research.

8.6 Concluding Remarks

This chapter discussed the summary of current scenario, existing role, challenges of urban wetland management and use on sustainable conservation and management of selected urban wetlands that extracted from study area stakeholder perceptions, from institutional stakeholder expert's perceptions and from author personal field observation according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1', the summary of water quality assessment and the summary of the applicability of the 'Urban Wetland Sustainability Framework (UWSF) Model – 2' across study area context.

CHAPTER - IX

CONCLUSIONS AND RECOMMENDATIONS

This chapter discussed the conclusions and recommendations that followed by the first, second, third, fourth and fifth objectives and research questions of the research.

9.1 Conclusions

From the overall findings and analysis, the research entails following conclusions:

9.1.1 Results of Objective - 1 and Research Question - 1

Urban wetlands are important for environmental, social and economic development of any city if it will properly conserve and managed in sustainable way. But currently, from the stakeholders' perceptions, this study identified that, there are limited role that have been played properly by most of these selected urban wetlands for different reasons and challenges. This research revealed that, the current scenario and existing role of selected urban wetlands have been identified according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1', as degradation of biodiversity status, low resilience to climatic impacts, limited provisions of livelihood, inconducive policy and low institutional embeddedness of community.

9.1.2 Results of Objective – 2 and Research Question – 2

Study indicates that, most of the selected urban wetlands have been degrading severely and in a serious threat mainly for anthropogenic and natural interventions and others challenges. Main associated challenges of selected urban wetlands management and use have been identified as wetlands water quality degradation by pollution through human interventions (by serious uncontrolled waste material and waste water pollution, inadequate sewerage connection and others) and natural activities (storm and rain water accumulation and mixed with surrounding harmful waste, waste water and finally store in the wetlands), unplanned urban development, reduction of water retention areas by encroachment, interrupting species diversity and ecological function of urban wetlands, destruction of habitat, affecting wetland species existence, endangered of wetland species day by day, severe fish mortality, affecting ideal water body criteria, interrupting natural drainage function and natural cleansing system of urban wetlands, failing the standard limit of maximum water quality parameters, lack of community involvement for biodiversity conservation, lack of awareness among public, endangering human health, unplanned land use, over population pressure, seasonal difference of water level interrupting biodiversity, climate change impacts, less importance has been giving on the value of biodiversity and ecosystem conservation, less awareness on conservation, lack of community and stakeholder involvement on conservation and management, degradation of ground water ecology, generation of heat in day time presently, presence of less quantities of big shaded trees surrounding some of the water bodies areas, water almost dried for six months in some study areas, increase of over paved concrete areas in the city that are producing heat, increase of daily atmospheric temperatures in the city day by day, raising the urban heat island effects, reduction of heat resistance capacity of these urban wetlands for filling and encroachment of wetland areas, serious air pollution, Particulate Matter (PM) deposition in the atmosphere, affecting human health and quality of urban life, shrinkages of water areas, siltation, destroying aquatic ecosystems by decreasing

Dissolved Oxygen (DO), depletion of species, improper drainage connection in some areas that causing water logging sometimes, losing internal connectivity of these water bodies, encroachment and filling of wetland areas by land grabbers, narrowing of water courses, reduction of sustainable capacity of urban wetlands, reduction of water holding capacity, reduction of water depth, interrupting natural drainage system, overloading of drainage systems, less capacity of drainage system, hampering functioning of main hydrological role for climate change impacts, bed level reduction of water bodies through accumulation of sludge, lack of proper functioning of drainage infrastructures, lower water level in winter and summer season, threat for aquatic vegetation, fishes, wildlife and other species, reduction of ground water availability in the warm summer season, risk of earthquake, high pollution load during high intensity of precipitation by climate change impacts, lot of livelihood restrictions on the urban context, bad smell of water in winter season, using of cultivated fishes for the lack of natural water fishes, use of external medicine for purify bad water, need to provide costly additional fish food and fish lings often in the water body, absence of commercial lease system on fishing in some urban wetlands, less income and economic return than the past, less economic dependency of wetland resource based livelihood, lack of financial support from Government organizations for fish and agricultural resource improvement and development, less presence of visitors in some area, lack of security and safety in some areas, presence of some unexpected people in the lake areas, limited access of tourism-based livelihood, less dependency on urban wetlands livelihood, uncontrolled pollution, less availability of wetland fishes, negligible consumption of urban wetlands fishes, negligible economic profit from urban wetland resource-based livelihood, interrupting fishing and agriculture-based livelihood, degradation of cultivated crops and fish quality for wetland bad water quality, reduction of crops yield, agricultural development, less scope on wetland resource dependent livelihood for local poor community people, most demanded local fresh water fishes have been replaced by culture and less demanded fish species for water quality degradation, lack of awareness on policies and adequacy of policy regime among stakeholders, lack of proper implementation of policies still now exists in water sectors for sustainable management, lack of management, lack of coordination among authorities, lack of political commitment, rules are respectively less, need to be improving more, lack of implementation of rules, lot of gaps between laws and strict enforcement, lack of following policies in effective way by different organization and peoples who are responsible for these urban water bodies, lack of following connecting laws actually on Ashulia and Birulia water bodies, lack of following properly Acts - Yr.2000 and rules - Yr.2005 along with Water law and Environment laws, over population is the main hindrance for the management of these urban wetlands in and around Dhaka city, lack of systems, overlooking 'Joladhar Songrokkon Aine' on maximum urban wetland management issues, lack of enforcement of policies, laws, regulations on source pollution and water quality improvement, lack of implementation of laws on public pollution of lake water by throwing wastes, lack of enforcement of policies on surrounding domestic, construction, sewerage, industrial and other urban waste pollution, encroachment of urban wetlands should be stopped by the proper laws as 'Joladhar Songrokkon Ain' and others, lack of implementation of policies on security and safety functions, lack of enforcement of policies on presence of unexpected people sometimes in the study areas, less Government support for water quality improvement, less Government support for fish resource improvement and development, lack of manpower for maintenance and security issues, lack of awareness on valuation of water bodies, lack of adequate secondary transfer stations for disposal of solid waste in the city, lack on water connecting planning by the higher authorities from the beginning in Dhaka city, lack of integrated water resource-based management, lack of adequate pollution measures by implementation of policies, lack of local level management, lack of sustainable conservation, maintenance and management of urban wetlands, lack of stakeholder perceptions on management, lack of community people involvement on planning, conservation and management, lack of proper waste management, lack of thinking of wetland connecting values and services, lack of coordination among all relevant organizations, lack of proper maintenance of existing drainage connections, lack of management on water quality improvement, pollution etc., lack of management on surrounding domestic, construction, sewerage, industrial and other urban waste pollution control, lack of management on awareness about environmental conservation and management by the public and relevant authorities, lack of management on security function in some urban wetlands' areas, there is no contribution on conservation and management at all, limited resources and power to handle all wetland connecting issues, lack of management from higher Government authorities towards conservation of the urban wetland etc.

9.1.3 Results of Objective - 3 and Research Question – 3

(1) From the water quality assessment for three months, this research identified that, Temperature, pH, Chemical Oxygen Demand (COD), Nitrate-Nitrogen (NO3-N), Total Dissolved Solid (TDS), Electrical Conductivity (EC) etc. are within the permissible limit of Environmental Quality Standard (EQS) that has been followed by the Department of Environment (DoE) and Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD5), Turbidity, Phosphate (PO4) are not within the permissible limit of (EQS) in maximum water bodies. Results revealed that, the water quality parameters of the selected maximum urban wetlands are highly dominated by anthropogenic and natural activities and in a serious risk for aquatic biodiversity conservation and ecosystem enhancement in the city. Likewise, we can see that, these water quality result's reflection from stakeholders' perceptions of these maximum wetlands those are nearly similar for aquatic biodiversity conservation that they described earlier.

(2) Among all selected seven urban wetlands, for Study area - 4: Ramna Lake, total eight parameters of water quality as Temperature, pH, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Nitrate-Nitrogen (NO3-N), Phosphate (PO4), Total Dissolved Solid (TDS), Electrical Conductivity (EC) have been found within the permissible limit of Environmental Quality Standard (EQS). Dissolved Oxygen (DO) values of both sample locations in three tested months of this urban water body (6.70 to 10.90 mg/L) have been identified within the EQS limit that indicated good water quality for aquatic biodiversity conservation on 'DO' results. If we see the overall current status and existing role from the stakeholders' perceptions on this water body, it's identified that, according to Attribute - 1: 'contribution for biodiversity conservation and enhancement', Study area - 4: Ramna Lake have been performing effective contribution of conservation on biodiversity for this lake, water quality is good (around 80 to 90% water is good), less polluted and less bad odor, suitable for fishes and other species to live, there is always standing water with required depth are found and for this reason, there are varieties of local fishes are available same as before like Rui (normally weight as 12 to 13 kg), Catla (normally weight as 20 to 25 kg), Shing, Magur, Tatkini, Puti, Chingri, Shole, Taki, Tilapia, Silver carp, Big Head Carp (Australian), Pangash (cultivated pangash) etc.), taste of fishes is good to eat as before, fish quality is almost same as it was before, fishes do not find dead floated on the water body normally except some times in rainy season, no outside outfalls or pipes are connected that can pollute the water of Ramna Lake by external waste and waste water, fishes consume natural food from lake water, no need to provide additional food from authorities, no need additional chemical or medicine for clean the lake water frequently ('City Division' of PWD authorities only use 'chun' within one year interval only if required by testing), fishes found in monsoon season more than winter season for enough availability of water, there are no harmful water-based plants that can destroy whole aquatic systems, cleaning staffs clean water submerged leaves from different trees and plants every day, different diverse other aquatic and terrestrial wildlife species are still have high conservation status in this water body etc.

(3) Another way, for Study area - 2: Gulshan-Baridhara Lake, total six parameters of water quality as Temperature, pH, Chemical Oxygen Demand (COD), Nitrate-Nitrogen (NO3-N), Total Dissolved Solid (TDS) and Electrical Conductivity (EC) have been found within the permissible limit of Environmental Quality Standard (EQS). But, Dissolved Oxygen (DO) values of both sample locations in two tested months (November and December) of this urban water body (0.0 to 2.80 mg/L) have been identified not within the EQS limit that indicated ‘bad water quality for aquatic biodiversity conservation’ on DO results. If we see the overall current status and existing role from the stakeholders’ perceptions on this water body, it’s identified that, this wetland has been performing less effective contribution of conservation on biodiversity as in this lake, water quality is not good, for bad water quality and smell (mainly in winter season), fishes also found with bad smell and taste, only Pangash, Magur, Tilapia etc. can live moderately, but other local carp type fishes as Rui, Katla cannot live in this bad quality of water, there number are very few here, when fish lings are providing in this lake water, nearly 5% to 10% fishes are died normally for bad quality of water firstly, in the past, the water was good, much varieties of local fish species as Chapila, Puti, Tangra, Chingree etc. can live here, but recent times for surrounding pollution, urban development, encroachment these fishes cannot live in this lake, every year fishes found floated dead on the top surface of the water body, fishes found dead when there is gas occurred in the lake water, for bad smell fish lease holders and fish farmers have been using potash, chun etc., need to provide additional fish food often instead of natural food in the lake water by ‘commercial fish lease holder’ authorities, water quality is so bad recently that, local people cannot even use lake water for bathing, washing etc. in this lake that they did in the past, once this lake was a good fishing ground for urban dwellers, many people from different parts of Dhaka city come to this lake for taking of fishes from here, that time those fishes were in a very good quality, once local people used to drank water from this lake, but now that situation completely changed, people cannot use lake water for drinking for bad water quality, surrounding pollution from domestic, industrial, clinical, construction waste and waste water from both sides of residential areas as Gulshan and Badda and from surrounding commercial areas destroying this water body, sewerage line connection from both sides of residential areas as Gulshan and Badda has been polluting the lake water, terrestrial biodiversity also have a big threat recently etc.

Therefore, we can see that, there is a close similarity between stakeholders inner thinking and the tested scientific results on the quality of the current status of wetland water in this study. Therefore, it is urgent need to involved stakeholders for future sustainable management of urban wetlands in the capital. This study can serve as a baseline reference for the researchers who wish to work on this field, but it cannot be a standard cause the surrounding location, seasonal variation, climatic variation, geographical, geomorphological, hydrological conditions of different urban wetlands in other places and other countries are not same and can vary widely with time.

9.1.4 Results of Objective - 4 and Research Question – 4

According to the ‘Urban Wetland Sustainability Framework (UWSF) Model – 2’, the study identified that, average Dissolved Oxygen (DO) concentration variation of maximum urban wetlands has been affected mainly by existing wetland management structures, water pollution from industrial effluent, population density, water pollution from sewerage effluent, air pollution and presence of surrounding shaded trees and vegetations in that order. From the analysis, this study showed that, if the number of total external factors are decreases then the average DO concentration across urban wetlands are increases. Another way, if the number of total external factors are increases, then the average DO concentration across urban wetlands are decreases. Therefore, there is a strong relation between the selected external factors and their influence with the average DO concentration variation across selected urban wetlands in this present research. Therefore, proper sustainable policies and management plan on all these factors need to be implemented for the selected urban wetlands respectively.

9.2 Recommendations

From the overall finding and analysis, the research entails following recommendations according to the 'Urban Wetland Sustainability Framework (UWSF) Model – 1 and 2' for sustainable management of selected urban wetlands:

9.2.1 Recommendations According to the Urban Wetland Sustainability Framework (UWSF) Model – 1

9.2.1.1 Attribute - 1: 'Contribution for biodiversity conservation and enhancement'

- At first, to identify the source of pollution and should stopped and manage them properly to maintain the water quality.
- As waste and waste water from domestic, industrial, hospital, clinical, restaurants and other sources polluted these urban wetlands, so strict management of these wastes should be ensured and modern waste management options should be introduced with low-cost example as foreign countries.
- For solid waste management, secondary transmission system should be constructed more in the city as a priority.
- Proper land use planning and their implementation should be ensured that it will not degrade water quality or obstruct any water area in the city.
- Direct sewerage connection from households, industries, hospitals, restaurants etc. should not give besides the urban wetlands.
- Water quality improvement should be given the first concern in all selected urban wetlands, as the whole aquatic and terrestrial species depends on this water.
- Adequate water depth and connectivity with other channels should be maintained to enrich proper ecosystem restoration and for enabling fish migration in different areas of urban wetlands.
- Urban wetlands should have good productivity in terms of aquatic species as plankton (phytoplankton, zooplankton, hydro plankton etc.), aquatic plants, insects and invertebrates to support fish and other water related fauna.
- Water quality has been degrading much recent years in selected all urban wetlands. Water purification plants (as water lily, lotus, Ipil-ipil etc.) are absent in selected lakes. So, it is urgent required to plant these species as soon as possible.
- Water lettuce, water hyacinth etc. has good filtration capacity, so these plants should be introduced in selected urban wetlands with adequate quantities.
- Native reed type plants can be an option for cleaning of polluted water as well.
- Different filter feeder animals as mollusk should be introduced in selected maximum urban wetlands for better filtration systems.

- The excess weeds in these urban wetlands should be cleaned frequently as these create acidification frequently.

- Urban wetlands should have a various stock of fishes and other aquatic species, breeding animals and plants that can serve large population in the city. In this case, over exploitation of urban wetland resources by people should be restricted for time basis and systematically.

- Urban wetlands should have an auspicious environment as good water quality in terms of standard limits and restricted from contamination. For these reasons, water quality test should be performed monthly and should compare it with the national and international guidelines and standards by relevant authorities (as Department of Environment (DoE), Fisheries Department etc. officially has been conducting monthly water test throughout the year in study area of Dhanmondi, Gulshan-Baridhara, Hatirjheel Lake, Turag River and Ramna Lake etc.), these tests should be done in other selected urban wetlands in Dhaka city as well.

- Adequate domestic, industrial and municipal waste and waste water management technology should be adapted to avoid water pollution by effluents that have harmful sediments, nutrients, heavy metals, different toxic materials loading. These management technologies will generate adequate environment for the aquatic species (fish, flora and fauna etc.) and other biodiversity in urban wetlands.

- Banks of these urban wetlands has been planted comparatively scenic view greenery, but there are to increase the panoramic view of the area, different categories of flowers plants and trees (local species) may be planted.

- Should plant adequate native swamp forest water attracted trees (hijal, koroch etc.) to restore swamp forest which is an important ecosystem component and habitat for fish, bird and other wildlife.

- Small Island may be formed inside the urban wetlands areas to give shelter or habitat for diverse seasonal local birds and other species to enhance terrestrial biodiversity.

- Different fruit trees and bird attracted trees should be planted surrounding the urban wetlands so that these can bring proper terrestrial ecosystem conservation, can connect whole aquatic ecosystems and shelter.

- There is a knowledge gap found on the term ‘biodiversity’ among public, so, documentation on biodiversity of urban, sub-urban, rural water bodies should be ensured through different biological laboratory test researches that public can aware and motivate towards on the biodiversity conservation and management. In connection to this, institutions, organizations etc. should provide financial support for the future researchers.

9.2.1.2 Attribute - 2: 'Resilience of urban/sub-urban water bodies to face the challenge of climate change impacts'

- Climate change impacts on urban wetlands are mainly as Heat Island Effect (HIE) by temperature rise and flooding by over precipitation within short time duration almost common in Dhaka city nowadays during summer and monsoon seasons. These should be taken into serious consideration in urban planning development and implementation considering the geo-morphology of Dhaka.

- For Heat Island Effect (HIE) in urban area, landscaping of the urban wetlands side areas and banks by creation of much shaded green belt may be initiated in this regard that will make the city's air cool, fresh and soothing while providing shade to pedestrians. Like water body, this plantation can also reduce the atmospheric temperature. These can also absorb the excess ground water, reduce solar radiation, air pollution, greenhouse effects, noise pollution and thus lend softness to the city's landscape.

- Proper and safe storm water drainage network systems should be ensured to manage the water logging in Dhaka city area.

- For flooding, it should be developed flood and drainage management tools, strategy and re-excavation of connecting urban wetlands after some years duration (presently doing in Ramna Lake about 6 to 7 feet by floating excavator), by dredging to increase the bed level (observed in Birulia sub-urban water body presently) to increase water holding and storage capacity (during heavy rainy season, Dhanmondi Lake observed overflowing the bank with less storage capacity within recent years) and to hold much water for fish and other aquatic species. A wider, well and proper designed drainage system should be developed and constructed for water logging problem during flooding.

- Short boundary treatment with green on the place of concrete or wooden can be arranged in order to increase visual accessibility among both sides of the urban wetlands which can make the user feeling recreational. All green areas should ensure a better water absorption capacity.

- Introduction of 'social forestation' concept in left over spaces, islands, nodes and lake sides' areas should be initiated. Creation of green belts as plant nurseries can be created in left over open spaces (observed surrounding in Dhanmondi Lake and Bottola Diabari Lake) which can ensure green chunks of breathing spaces for urban dwellers.

- Agro forestry can be a good initiative for Green House Gas (GHGs) reduction besides walkway of the selected urban wetlands and surroundings. In connection to this, cultivation of bamboo on the urban wetlands surrounding is highly recommended.

- For less emission of greenhouse gas (CO_2, CH_4, N_2O etc.), Compressed Natural Gas (CNG) should be the top most priority for maximum vehicles within selected fresh water body surroundings and it's better to use renewable sources of energy in all sectors as well.

- Uses of solar panels instead of electricity should be ensured within selected urban wetlands surroundings areas for minimize maximum energy consumption.

- Recently climate change is a burning issue in Bangladesh. Government and other organization are trying to integrate this issue into all aspects of development work. But this process is much slow for the future improvement. So, incorporating this climate change issue in all sectors is highly recommended.

- Till to date a few research studies based on 'implications of climate change on fresh water ecosystem in Dhaka city' has been articulated. So, it needs different multi-dimensional study for the present declining situation of fresh urban wetlands in Dhaka city.

9.2.1.3 Attribute - 3: 'Contribution for community livelihood'

- Selected urban wetlands can provide a critical source of income and livelihood development for thousands of communities based floating local people by fishing, collection of other aquatic resources etc. that will directly and indirectly help to support these people in many ways. If proper commercial pisciculture will be introduced widely, then a large number of people can develop their livelihood and income from these urban water bodies.

- Recreational catch fisheries may also be introduced in all urban wetlands as Dhanmondi Lake, Ramna Lake, Bottola Diabari Lake etc. for livelihood and income.

- To construct floating garden (local name 'boira') by create bed of water hyacinth starting from water edges longitudinally throughout the water bodies for cultivation of agricultural seasonal crops for economic profit and livelihood without using chemical fertilizer and much soil (as Gopalganj, Barishal, Pirojpur village-based water bodies).

- Use of local cow dung and other organic fertilizer (observed in Diabari Bottola Lake) should be introduced in the place of chemical fertilizer (observed in Ashulia and Birulia wetland) to get rid of from harmful nutrients (nitrogen and phosphorous) and environment friendly maximum crops production for livelihood.

- To create vegetable macha (as lau, kumra, puishak, sim etc.) on the bank side slope area for livelihood of community people (as Gulshan-Baridhara Lake Badda bank side area).

- To introduce poultry activities of duck, swan etc. in water bodies for livelihood and economic returns of local people as Ashulia urban wetland for a good example.

- As water bodies were traditionally an important transport corridor in the Dhaka city area, so it's urgent need to implement proper utilization of different water transport (example as Hatirjheel Lake) in lake areas (mainly Dhanmondi to connect water ways with road no. 32 ghat, road no. 27 ghat, road no. 8 Bridge point ghat, Bachelor point ghat, road no. 2 ghat etc.) and Gulshan-Baridhara Lake) to reduce vehicular traffic congestion in the city and to increase livelihood development and maximum economic profit widely. It will definitely reduce the traffic jam, employment opportunities and economic profit within these areas as well.

- There are considerable numbers of food corner and mobile restaurant in some urban wetland’s areas, but those are expensive to fulfill the demand of public sometimes, so, efforts should be taken to establish more shop with reasonable price for the public. This will also enhance the livelihood of the local people.

- To introduce small vendors in a specific area of water bodies to increase their livelihood and that will not hamper the wetland environment.

- Development of commercial nursery on the bank of urban wetlands for livelihood purposes (presently used commercially in Diabari Bottola Lake, Dhanmondi Lake and Uttora Lake bank etc.).

- To plant and conserve huge white-water lily, kolmi and helencha shak in and around the water bodies for vegetable consumption commercially and for livelihood development; to plant mosaic plant as ‘panifol’ in the urban wetlands for fruit consumption and livelihood.

- To plant lot off lotus and water lily seeds widely for sell to the public for economic profit and livelihood.

- To plant short time fruit bearing trees as guava, lemon, papaya, green coconut (Thailand varieties), banana etc. on the bank of urban wetlands after some distances, when trees will plant, it should be keep in mind that it will never obstruct the scenic view of the lake, these fruit trees will help urban dwellers economic profit and employment generation.

- To plant huge native medicinal, wood trees to create urban forest on both the bank of urban wetlands for economic profit and livelihood activities.

- To introduce local people on waste management activities, cleaning and water quality improvement functions to improve their livelihood.

9.2.1.4 Attribute - 4: ‘Adequacy of the policy regime’

- Maximum respondents observed a much lack of knowledge on policies, laws, regulations in all selected urban wetlands, so awareness of these Government policies should be ensured by the authorities by creating different urban wetlands-based workshops to enhance the knowledge gap of policies.

- Environmental policies, water policies, climate change related policies, enforcements, laws, standards, taxes and regulations, Pollution Abatement Strategy, Climate Protection Strategy should be followed and implement properly.

- Importance should be given on areas like solid waste management and recycling activities, ban of non-recyclable materials, treatment of waste water effluent before disposal in water bodies to develop low cost Waste Water Treatment Plant, introduction of Green Transport Network, should undertake various conservation and management strategies for biodiversity enhancement and ecosystem preservation, demonstration of renewable energy, effective application of the Environmental Impact

Assessment (EIA) system, annual renewals of Environmental Clearance Certificates etc.

- As water bodies filling and illegal encroachment is the most common problem in Dhaka city nowadays (observed in Gulshan-Baridhara Lake and Ashulia wetland) which reducing the retention capacity of storm water and damaging open space areas of the urban wetlands. Therefore, it's should strictly implement appropriate acts and regulations immediately to protect those water body and water body side land areas from land grabber.

- Sustainable urban wetlands conservation and management must be the first concern for any economic development of the city. For these reasons, all these urban wetlands should include in Detailed Area Plan (DAP) and other related Plan in Dhaka city effectively.

9.2.1.5 Attribute - 5: 'Local acceptance and credibility of the role of relevant institutions'

- Water bodies, lakes and wetlands are the hearts and vital components of the green infrastructure needed in sustainable cities. Well-designed water bodies can become the centerpiece of future urban developments. Hence, a successful planning, design and management of these water bodies are urgent required by relevant authorities.

- The master plan of the city needs to be revised and updated every year. Thus, proper co-ordination among Government, Non-Government, Private Organizations, Water resource experts, Policy makers, Socio-economists, Town-planners, Environmentalists, Engineers, Architects and other stakeholders of national level should be existed.

- Better management should be adapted to the urban wetland and wetland side areas for the recreational purposes by concerned authorities to improve aesthetics and opportunities for cultural, sightseeing and recreational purposes. Should implement different recreational use for people as level designed walkway space for morning, evening exercise and jogging purposes, smooth path for cycling track, fishing and boating facilities, plantation of different flowers and green plant garden, different small restaurants for low cost food facilities to create user attractions, designed recreational hanging platform in the waterfront lake side areas and wide ghats for fishing and bathing purposes (present in Hatirjheel and Dhanmondi Lake widely).

- To attract the children of the surrounding locality, a small children park may be established (present in Dhanmondi and Ramna Lake and has been constructing in Hatirjheel Lake). Should conserve in that way that it should attract local, national and international tourist as well.

- Different amenities as solid waste garbage bins (less quantity observed in Dhanmondi, Gulshan-Baridhara, Diabari Lake, and Ashulia, Birulia wetland areas) proper sitting arrangements (less observed in Gulshan-Baridhara Lake etc.), drinking water facilities (observed less in all selected urban wetlands areas), hygienic defecation places (less observed in maximum selected urban wetlands), different lighting facilities for night time safety etc. should developed by concern authorities.

- Should locate and demarcation of the lake area for fixing the lake boundary accurately.

- Should implement proper selected solid and other waste disposal sites that far from water bodies to avoid pollution, degradation of urban wetlands.

- Should increase water connectivity of the urban wetlands with other different water bodies as Canals, Rivers etc. for effective natural purification system of urban wetlands.

- During survey it was observed that, maximum respondents do not have any idea about the term ‘biodiversity’ and ‘climate change’, so, awareness should be rise among public on these burning issues by relevant authorities.

- Awareness should be rise among public on biodiversity conservation, pollution etc. as well as wetland conservation and management through different community training and workshops, religious areas, media, add making, political parties’ awareness campaign, School, College, University, Madrasa, Institutions etc.

- Involvement of community based local people should be given the top most priority on urban wetlands conservation, management and livelihood activities with all authorities as they are the main user community and have a wide traditional background and knowledge on water bodies (partially developed in Dhanmondi Lake and Gulshan-Baridhara Lake). These local people’s comments can be an important part to take any decision on conservation and management of these urban wetlands in the city by the Government authorities.

- Concerned authorities should follow building construction rules and laws strictly in urban planning development. Different illegal structures should be removed by concerned authorities which obstructs the natural flow of water in the lake (as temporary Mosque already removed and BGMEA building is removing from Hatirjheel water body recently).

- Waterfront high rise buildings very close to the urban wetlands water way should be avoided which obstructs the aesthetical views of water bodies and dominating the edge of the urban wetlands.

- Respondents mentioned about urban wetlands safety and security of some selected urban wetlands. So, importance should be given the most on these issues for use of community people and visitors to avoid and maintain unusual crime and entry of unexpected people. Monitoring and maintenance of these areas in a fixed duration it’s a must by relevant security authorities as well.

- Co-ordination of different relevant organizations should be ensured.

- A single organization should be set for all urban wetlands’ development work in the city.

- Relevant stakeholders should be involved in planning, implementation, decision making and all other development phases to ensure a sustainable urban wetland management in the capital as well.

9.2.2 Recommendations According to the Urban Wetland Sustainability Framework (UWSF) Model – 2

- Proper sustainable policies and management plan on selected external factors as existing wetland management structures, water pollution from industrial effluent, population density, water pollution from sewerage effluent, air pollution and presence of surrounding shaded trees and vegetations need to be implemented for the selected sustainable urban wetlands management respectively as there is a strong relation between the selected external factors and their influence with the average DO concentration variation across selected urban wetlands in this present research.

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Appendix - 1

[A] Sample Questions of Semi-Structured Questionnaire Survey for Study Area Stakeholder according to Urban Wetland Sustainability Framework (UWSF) Model – 1

Gender -

Age -

Status of Study Area Stakeholder -

Daily income -

Table - 1: Sample Questions of Semi-structured Questionnaire Survey for Study Area Stakeholder according to Urban Wetland Sustainability Framework (UWSF) Model – 1

SL. No.	Questions
	Attribute - 1: 'Contribution for biodiversity conservation and enhancement'
01.	Name the type of aquatic and terrestrial plants, fish, animal, tree, wildlife, bird species those are available in this water body
02.	Do you think this water body is suitable for aquatic and terrestrial species to live, then what scale/rank will you mark for this water body on 'suitability for aquatic and terrestrial species to live' and why? - Very effective contribution - Effective contribution - Moderately effective contribution - Less effective contribution - Not effective at all
03.	What are the specific challenges of water body on biodiversity conservation and enhancement?
04.	Mention some of future suggestions for improvement on 'suitability for aquatic and terrestrial species to live' of this water body
	Attribute - 2: 'Resilience of urban wetlands to face the challenges of climate change impacts'
(a) Cooling effect during summer on heat stress of selected urban wetlands	
05.	Do you feel any cool environment during summer when you come close to this water body than other areas in the city, then what scale/rank will you mark for this water body on this 'cool environment' and why? (on heat stress during summer) - Very effective resilience - Effective resilience - Moderately effective resilience - Less effective resilience - Not effective at all
06.	What are the specific challenges of water body on 'cool environment'?
07.	Mention some of future suggestions for improvement on 'cool environment' of this water body
(b) Storage capacity during heavy rainfall on flood stress of selected urban wetlands	
08.	Do you think this water body is suitable for rain/flood/storm water storage during heavy rainfall, then what scale/rank will you mark for this water body on this 'storage capacity during heavy rainfall' and why? (on flood stress during heavy rainfall) - Very effective resilience - Effective resilience - Moderately effective resilience - Less effective resilience - Not effective at all
09.	What are the specific challenges of water body on 'storage capacity during heavy rainfall'?
10.	Mention some of future suggestions for improvement on 'storage capacity during heavy rainfall' of this water body

Attribute - 3: 'Contribution for community livelihood'	
11.	Name the type of community livelihood that present in surrounding this water body
12.	Name the type of crops that relevant for agriculture-based livelihood, the type of fishes that relevant for commercial fishing-based livelihood, the type of fishes that much relevant for angling/sport fishing, the type of natural water fishes that relevant for livelihood (if any), the type of vendor's activities that present surrounding this water body
13.	Do you think this water body is suitable for community livelihood contribution, then what scale/rank will you mark for this water body on 'contribution for community livelihood' and why? - Very effective contribution - Effective contribution - Moderately effective contribution - Less effective contribution - Not effective at all
14.	What are the existing and potential livelihood activities pattern and their yearly net income (approximately)?
15.	What are the specific challenges of water body on contribution for community livelihood?
16.	Mention some of future suggestions for improvement on 'contribution for community livelihood' of this water body
Attribute - 4: 'Adequacy of the policy regime'	
17.	Do you have any idea about Government policies, regulations and laws connecting on these urban water bodies in Bangladesh, then name those policies, regulations and laws?
18.	Do you think are these policies, regulations and laws are adequate for conservation of this water bodies or not?
19.	What scale/rank will you mark for these policies on adequacy? - Very effective contribution - Effective contribution - Moderately effective contribution - Less effective contribution - Not effective at all
20.	What are the specific challenges on the policy regime?
21.	Mention some of future suggestions for improvement on 'policy regime'
Attribute - 5: 'Local acceptance and credibility of the role of relevant institutions'	
22.	Mention some of relevant organizations/institutions that has been working on this water body
23.	Discuss separately their role
24.	Mention the best organizations according to you that performing well on this urban water body according to you and what scale/rank will you mark for these organizations and why? - Very effective contribution - Effective contribution - Moderately effective contribution - Less effective contribution - Not effective at all
25.	What are the specific challenges on the 'role of relevant institutions/organizations?

26.	Mention some of future suggestions for improvement on the ‘role of relevant institutions’

[Notes: Selected five-point Likert scales of very effective contribution, effective contribution, moderately effective contribution, less effective contribution and not effective at all have been extracted by the study area stakeholders as very good contribution, good contribution, medium contribution, less contribution and no contribution at all for the understanding the perceptions of current scenario and existing role on the selected urban wetlands in the field according to Urban Wetland Sustainability Framework (UWSF) Model – 1]

[B] Sample Questions of Semi-Structured Interview for Institutional Stakeholder Expert according to Urban Wetland Sustainability Framework (UWSF) Model – 1

Name of the Organization/Institution -

Position of the institutional stakeholder expert -

Table - 2: Sample Questions for Semi-structured Interview for Institutional Stakeholder Expert according to Urban Wetland Sustainability Framework (UWSF) Model – 1

SL. No.	Questions
Attribute - 1: ‘Contribution for biodiversity conservation and enhancement’	
01.	What scale/rank will you mark for these water bodies on ‘contribution for biodiversity conservation and enhancement’ and why? - Very effective contribution - Effective contribution - Moderately effective contribution - Less effective contribution - Not effective at all
02.	What are the specific challenges of these water bodies on biodiversity conservation and enhancement?
03.	Mention some of future suggestions for improvement on ‘contribution for biodiversity conservation and enhancement’ of these water bodies
Attribute - 2: ‘Resilience of urban wetlands to face the challenges of climate change impacts’	
(a) Cooling effect during summer on heat stress of selected urban wetlands	
04.	What scale/rank will you mark for these water bodies for ‘cooling effect’ during summer on ‘resilience to face the challenges of climate change impacts’ and why? - Very effective resilience - Effective resilience - Moderately effective resilience - Less effective resilience - Not effective at all
05.	What are the specific challenges of these water bodies for ‘cooling effect’ on resilience to face the challenges of climate change impacts?
06.	Mention some of future suggestions for improvement for ‘cooling effect’ on ‘resilience to face the challenges of climate change impacts’ of these water bodies
(b) Storage capacity during heavy rainfall on flood stress of selected urban wetlands	
07.	What scale/rank will you mark for these water bodies for ‘storage capacity during heavy rainfall’ on ‘resilience to face the challenges of climate change impacts’ and why? - Very effective resilience - Effective resilience - Moderately effective resilience - Less effective resilience - Not effective at all
08.	What are the specific challenges of these water bodies for ‘storage capacity during heavy rainfall’ on resilience to face the challenges of climate change impacts?
09.	Mention some of future suggestions for improvement for ‘storage capacity during heavy rainfall’ on ‘resilience to face the challenges of climate change impacts’ of these water bodies

Attribute - 3: 'Contribution for community livelihood'	
10.	What scale/rank will you mark for these water bodies on 'contribution for community livelihood' and why? - Very effective contribution - Effective contribution - Moderately effective contribution - Less effective contribution - Not effective at all
11.	What are the specific challenges of these water bodies on contribution for community livelihood?
12.	Mention some of future suggestions for improvement on 'contribution for community livelihood' of these water bodies
Attribute - 4: 'Adequacy of the policy regime'	
13.	Name the type of Government policies, regulations and laws that has been following by your organizations or other institutions on these water bodies?
14.	Do you think are these policies, regulations and laws are adequate for conservation of these water bodies or not?
15.	What scale/rank will you mark for these policies on 'adequacy' and why? - Very effective contribution - Effective contribution - Moderately effective contribution - Less effective contribution - Not effective at al
16.	What are the specific challenges on the policy regime?
17.	Mention some of future suggestions for improvement on 'policy regime' of these water bodies
Attribute - 5: 'Local acceptance and credibility of the role of relevant institutions'	
18.	Mention some of relevant institutions/ organizations those are working on these water bodies
19.	Discuss separately their role
20.	Mention the best organizations according to you that performing well on these urban water bodies?
21.	What scale/rank will you mark for these organizations on 'their role' and why? - Very effective contribution - Effective contribution - Moderately effective contribution - Less effective contribution - Not effective at all
22.	What are the specific challenges on the role of relevant institutions/organizations?
23.	Mention some of future suggestions for improvement on 'the role of relevant institutions' of these water bodies

Appendix - 2

[A] Status of Study Area Stakeholder

Gender -

Age -

Status of Study Area Stakeholder -

Daily income -

Table - 3: Socio-economic Status of Study Area Stakeholder

Sl. no.	Socio-economic Status of Study Area Stakeholder	In percentage (%)
01.	**Gender**	
[a]	Male	92.38 %
[b]	Female	7.61 %
02.	**Age (17 to 65 years)**	
[a]	17 - 27 yrs	22.38 %
[b]	28 - 38 yrs	45.23 %
[c]	39 - 49 yrs	23.81 %
[d]	> 49 yrs	8.57 %
03.	**Status of Stakeholder**	
[a]	Vendors/hawkers	38.09 %
[b]	Stakeholder with indirect livelihood activities (e.g. as small shops owners for tea, cigarette, cake etc., water transport staff, small restaurant staff, mobile small restaurant staff, big permanent restaurant staff, security guards, etc., cleaning staff, stakeholder on nursery activities, stakeholder on easy bike activities, stakeholder on horse cart activity etc.)	23.33 %
[c]	Stakeholder with direct livelihood activities (e.g. as amechar fishermen, fish farmers, agricultural farmer, daily labor for agricultural activities, poultry farmer, labor for brick manufacturing work, boatmen etc.)	11.90 %
[d]	Others (e.g. as neighborhood people, local people, visitors etc.)	26.67 %
04.	**Daily income (in taka) (approx.) (250 to 7000 taka/day)**	
[a]	Up to 1,000 taka/day	43.80 %
[b]	1,001 to 2,000 taka/day	6.67 %
[c]	2,001 to 3,000 taka/day	3.33 %
[d]	> 3,000 taka/day	0.47 %
[e]	No income information from wetland	45.71 %

Appendix - 3

[A] Collected Water Sample Locations and Water Quality Test Results Across Seven Study Areas

Table - 4: Collected Water Sample Locations Across Seven Study Areas

Study Area	Sample number	Sample Location
Study area - 1: Dhanmondi Lake	S - 01	At the in front of Dhanmondi Lake Masjid location (opposite side of 32 no. road)
	S - 02	At near the Panshi restaurant of north side of 8 no. Bridge
Study area - 2: Gulshan-Baridhara Lake	S - 01	Back side of United Hospital, Gulshan-Baridhara Road
	S - 02	Baridhara Park area
Study area - 3: Hatirjheel Lake	S - 01	Besides the Jheel Kutum restaurant
	S - 02	Water Taxi Terminal point (between Police Tower and middle of Rampura Bridge Road sides)
Study area - 4: Ramna Lake	S - 01	Near to Ramna Chinese restaurant
	S - 02	Near to Ramna main gate point
Study area - 5: Bottola Dia Bari Lake	S - 01	Near to 10 no. Bridge
	S - 02	Near to 11 no. Bridge
Study area - 6: Ashulia wetland	S - 01	Left side of Ashulia Highway Road
	S - 02	Right side of Ashulia Highway Road
Study area - 7: Birulia wetland	S - 01	Birulia and Turag River Distributaries Ghat point
	S - 02	Turag River Distributaries middle point

Table – 5: Collected Water Sample Locations Across Seven Study Areas

Study area	Sample - 01	Sample - 02
Study area – 1: Dhanmondi Lake		
Study area – 2: Gulshan-Baridhara Lake		
Study area – 3: Hatirjheel Lake		

Study area – 4: Ramna Lake		
Study area – 5: Diabari Bottola Lake		
Study area – 6: Ashulia urban wetland		

Study area – 6: Birulia urban wetland		
Collected samples		

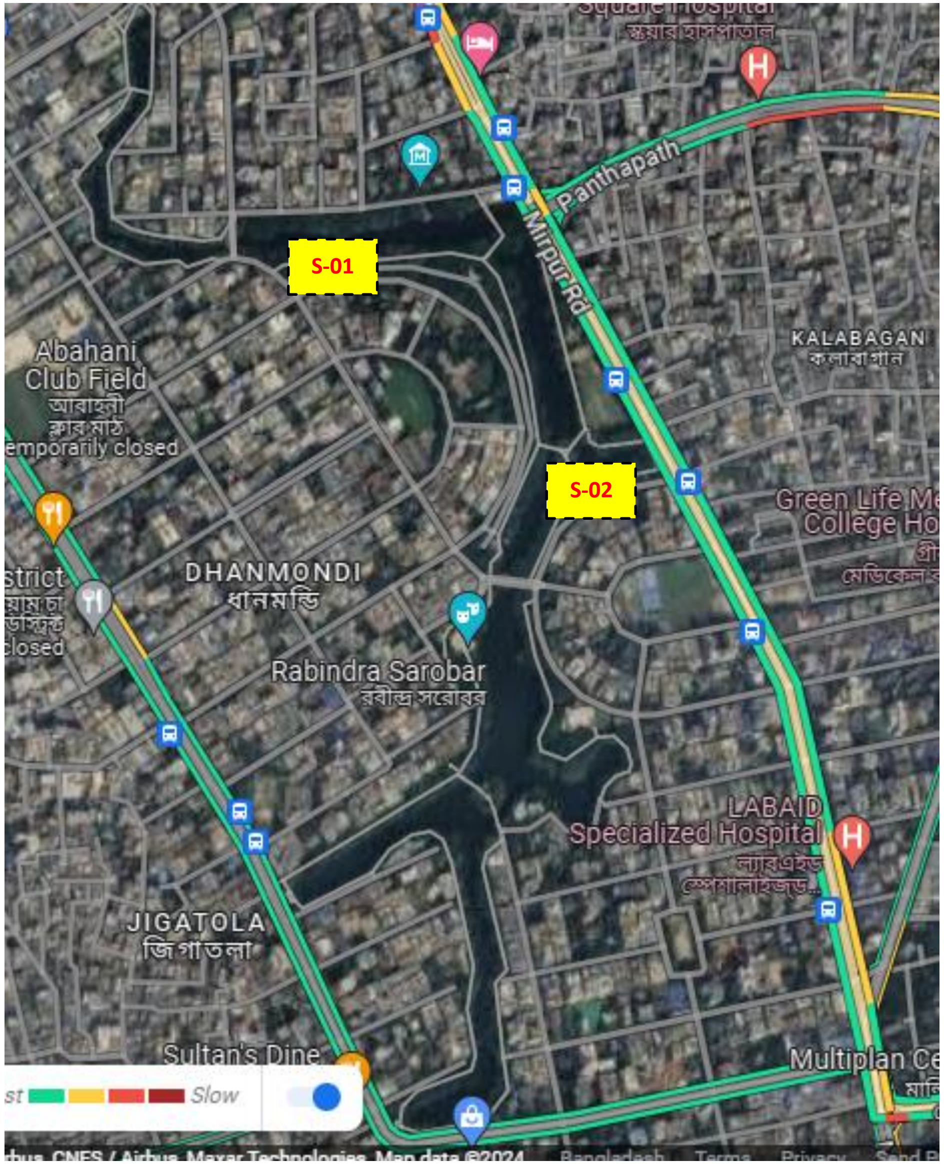


Figure- 01: Water sample location of Study area – 1: Dhanmondi Lake

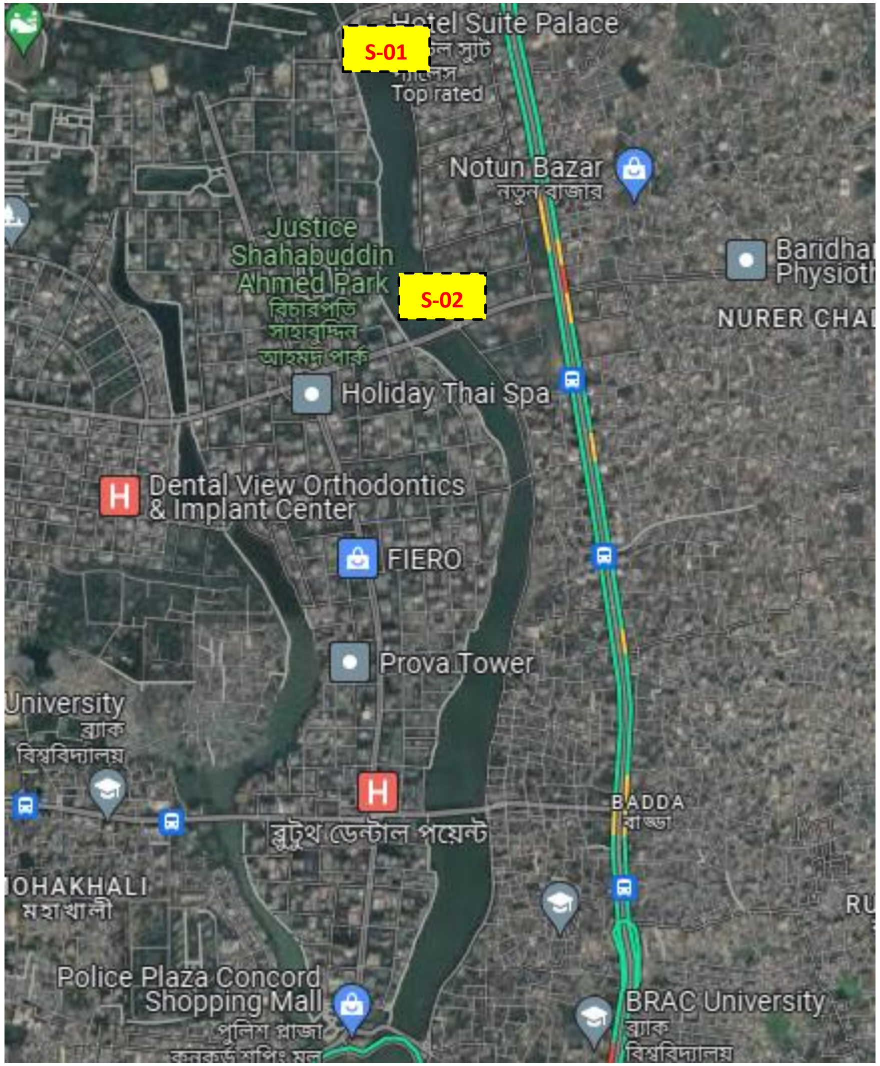


Figure- 02: Water sample location of Study area – 2: Gulshan-Baridara Lake

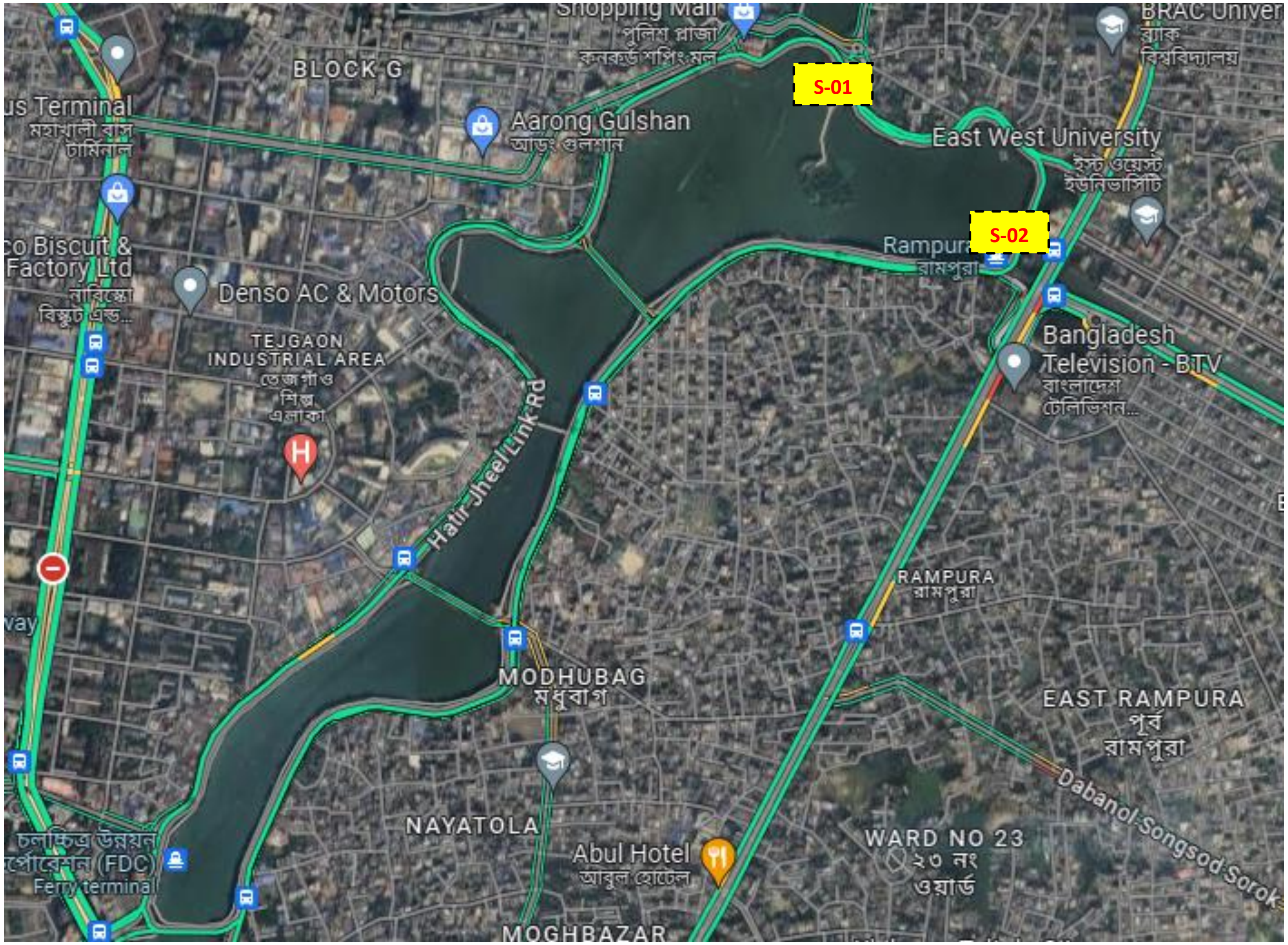


Figure- 03: Water sample location of Study area – 3: Hatirjheel Lake

Figure- 04: Water sample location of Study area – 4: Ramna Lake

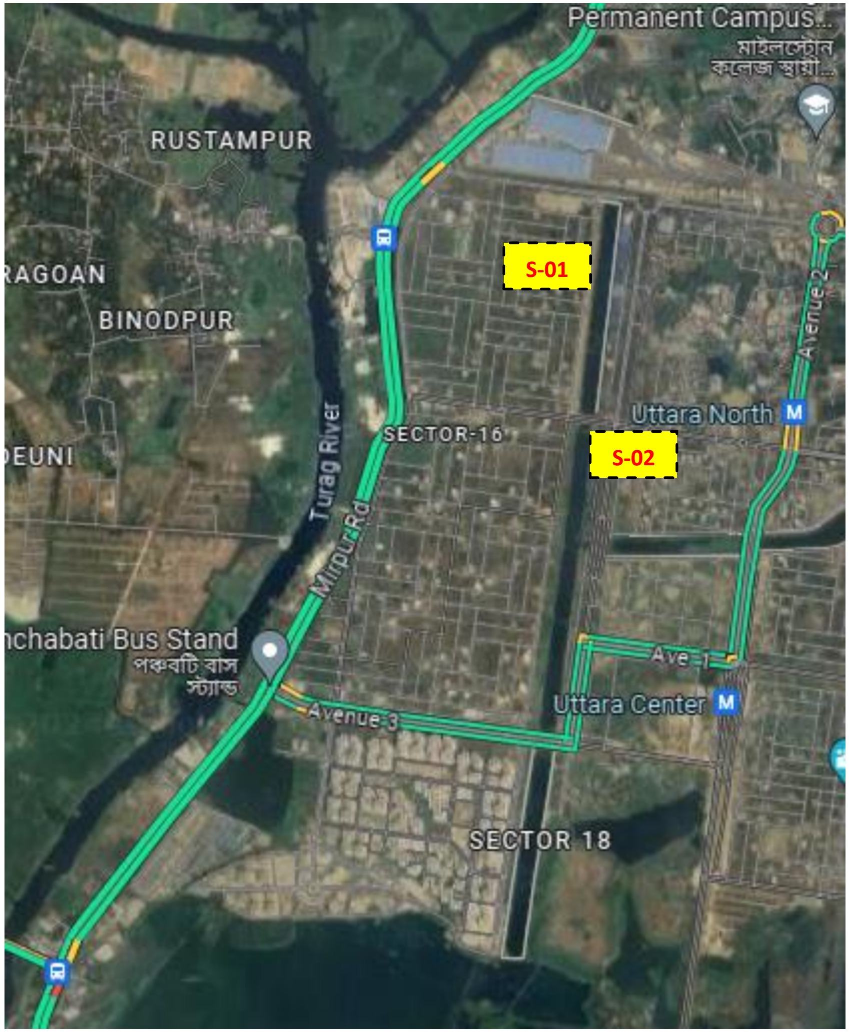


Figure- 05: Water sample location of Study area – 5: Diabari Uttara Lake

Figure- 06: Water sample location of Study area – 6: Ashulia Urban Wetland

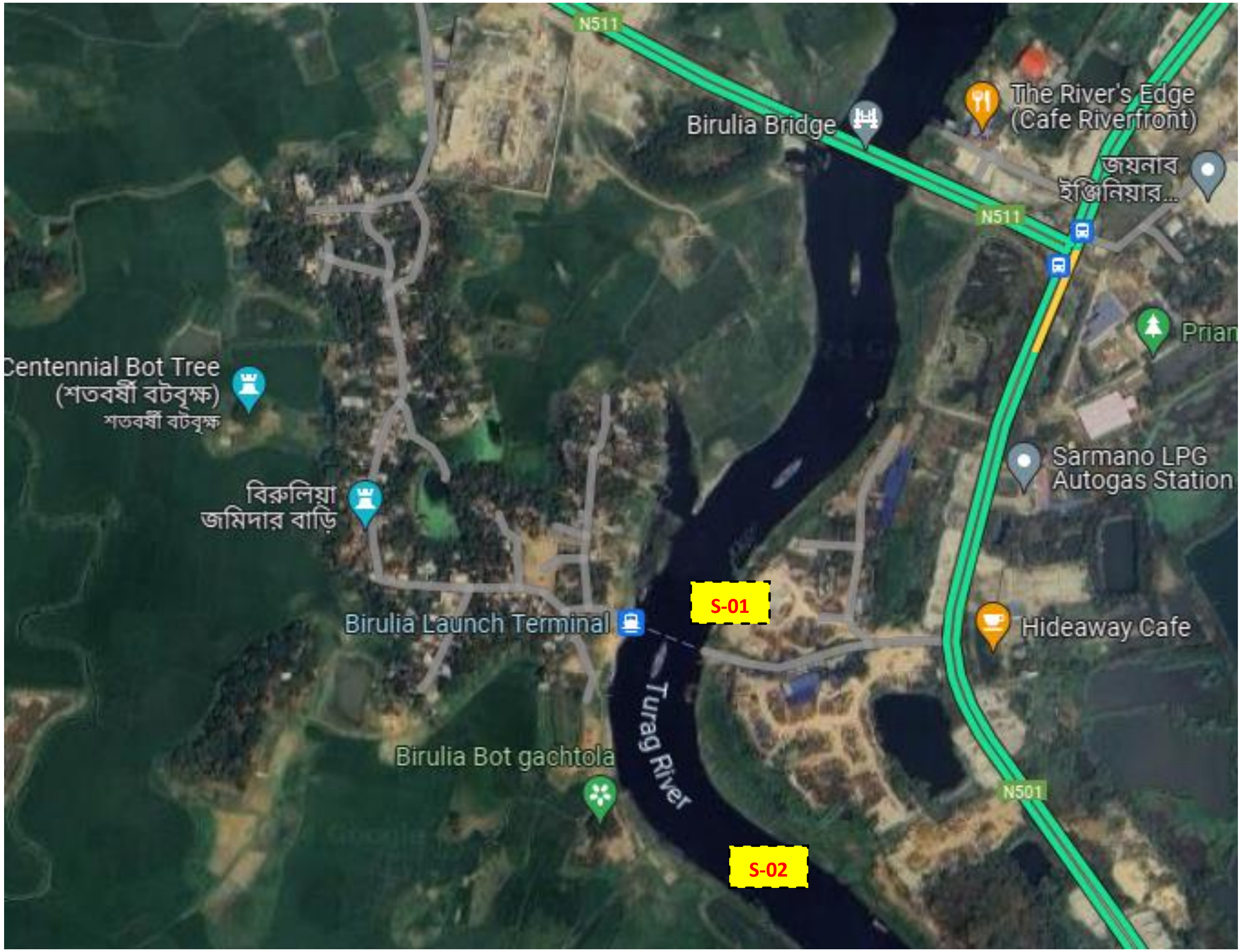


Figure- 07: Water sample location of Study area – 7: Birulia Urban Wetland

Table - 6: Water Temperature Test Results Across Seven Study Areas

SL no.	Water quality parameters	Study area	Sample number	Value of three months (°C)			Average value (°C)	EQS
				October (2020)	November (2020)	December (2020)		
01.	**Water Temperature (°C)**	Study area - 1: Dhanmondi Lake	S - 01	19.6	**23.6**	**16.7**	**19.98**	**20 to 30°C**
			S - 02	19.2	23.4	17.4		
		Study area - 2: Gulshan-Baridhara Lake	S - 01	19.5	23.3	**18.6**	**20.58**	
			S - 02	19.7	**23.7**	18.7		
		Study area - 3: Hatirjheel Lake	S - 01	19.5	**23.9**	**16.8**	**20.07**	
			S - 02	19.8	23.6	**16.8**		
		Study area - 4: Ramna Lake	S - 01	19.4	23.0	18.8	**20.35**	
			S - 02	19.5	**23.2**	**18.2**		
		Study area - 5: Bottola Dia Bari Lake	S - 01	19.4	23.1	**18.1**	**20.28**	
			S - 02	19.6	**23.2**	18.3		
		Study area - 6: Ashulia wetland	S - 01	19.6	23.5	**18.0**	**20.38**	
			S - 02	19.5	**23.7**	**18.0**		
		Study area - 7: Birulia wetland	S - 01	19.8	**23.9**	18.3	**20.62**	
			S - 02	19.8	23.8	**18.1**		

Table - 7: pH Test Results Across Seven Study Areas

SL no.	Water quality parameters	Study area	Sample number	Value of three months			Average value	EQS
				October (2020)	November (2020)	December (2020)		
02.	**pH**	Study area - 1: Dhanmondi Lake	S - 01	**7.53**	7.46	**6.93**	**7.29**	**6.5 to 8.5**
			S - 02	7.42	7.47	**6.93**		
		Study area - 2: Gulshan-Baridhara Lake	S - 01	**7.46**	**7.03**	7.27	**7.25**	
			S - 02	7.37	7.04	7.31		
		Study area - 3: Hatirjheel Lake	S - 01	7.38	7.35	7.27	**7.34**	
			S - 02	**7.40**	7.37	**7.24**		
		Study area - 4: Ramna Lake	S - 01	7.58	**6.94**	7.52	**7.37**	
			S - 02	**7.60**	7.31	7.26		
		Study area - 5: Bottola Dia Bari Lake	S - 01	**7.86**	7.31	7.51	**7.55**	
			S - 02	7.83	**7.28**	7.53		
		Study area - 6: Ashulia wetland	S - 01	**7.51**	7.45	**7.25**	**7.39**	
			S - 02	7.44	7.43	7.26		
		Study area - 7: Birulia wetland	S - 01	**7.50**	7.29	**7.22**	**7.33**	
			S - 02	7.41	7.31	7.26		

Table - 8: Dissolved Oxygen (DO) Test Results Across Seven Study Areas

SL no.	Water quality parameters	Study area	Sample number	Value of three months (mg/L)			Average value (mg/L)	EQS
				October (2020)	November (2020)	December (2020)		
03.	**Dissolved Oxygen (DO)**	Study area - 1: Dhanmondi Lake	S - 01	6.70	6.00	**3.80**	**7.03**	>_5 mg/L
			S - 02	6.80	**10.0**	8.90		
		Study area - 2: Gulshan-Baridhara Lake	S - 01	**6.10**	0.60	2.80	**3.03**	
			S - 02	6.00	**0.00**	2.70		
		Study area - 3: Hatirjheel Lake	S - 01	5.60	3.80	6.00	**5.17**	
			S - 02	5.80	**0.00**	**9.80**		
		Study area - 4: Ramna Lake	S - 01	8.40	**6.70**	6.80	**8.22**	
			S - 02	8.50	8.00	**10.90**		
		Study area - 5: Bottola Dia Bari Lake	S - 01	8.80	3.50	6.90	**6.77**	
			S - 02	8.60	**2.60**	**10.20**		
		Study area - 6: Ashulia wetland	S - 01	**7.50**	5.80	3.50	**5.63**	
			S - 02	7.30	6.40	**3.30**		
		Study area - 7: Birulia wetland	S - 01	**8.00**	4.30	**1.80**	**5.12**	
			S - 02	7.90	3.40	5.30		

Table - 9: Biochemical Oxygen Demand (BOD5) Test Results Across Seven Study Areas

SL no.	Water quality parameters	Study area	Sample number	Value of three months (mg/L)			Average value (mg/L)	EQS
				October (2020)	November (2020)	December (2020)		
04.	**Biochemical Oxygen Demand (BOD5)**	Study area - 1: Dhanmondi Lake	S - 01	12.0	**13.0**	9.0	**10.08**	**<_6 mg/L**
			S - 02	11.5	**6.0**	9.0		
		Study area - 2: Gulshan-Baridhara Lake	S - 01	29.0	30.0	**23.0**	**26.42**	
			S - 02	**30.5**	**23.0**	**23.0**		
		Study area - 3: Hatirjheel Lake	S – 01	**46.0**	12.0	25.0	**27.03**	
			S - 02	43.2	**10.0**	26.0		
		Study area - 4: Ramna Lake	S - 01	7.00	**12.0**	5.0	**6.63**	
			S - 02	7.80	**3.0**	5.0		
		Study area - 5: Bottola Dia Bari Lake	S - 01	**3.00**	5.0	**14.0**	**7.13**	
			S - 02	3.80	**3.0**	**14.0**		
		Study area - 6: Ashulia wetland	S - 01	6.00	**12.0**	**2.0**	**5.67**	
			S - 02	7.00	5.0	**2.0**		
		Study area - 7: Birulia wetland	S - 01	4.00	13.0	19.0	**10.47**	
			S - 02	3.80	**3.0**	**20.0**		

Table - 10: Chemical Oxygen Demand (COD) Test Results Across Seven Study Areas

SL no.	Water quality parameters	Study area	Sample number	Value of three months (mg/L)			Average value (mg/L)	EQS
				October (2020)	November (2020)	December (2020)		
05.	**Chemical Oxygen Demand (COD)**	Study area - 1: Dhanmondi Lake	S - 01	41.0	33.0	44.0	**33.17**	**200 mg/L**
			S - 02	**45.0**	19.0	**17.0**		
		Study area - 2: Gulshan-Baridhara Lake	S - 01	173.0	131.0	71.0	**116.50**	
			S - 02	**180.0**	78.0	**66.0**		
		Study area - 3: Hatirjheel Lake	S - 01	151.0	**29.0**	63.0	**86.67**	
			S - 02	**158.0**	53.0	66.0		
		Study area - 4: Ramna Lake	S - 01	139.0	30.0	29.0	**64.67**	
			S - 02	**142.0**	**16.0**	32.0		
		Study area - 5: Bottola Dia Bari Lake	S - 01	22.0	28.0	**37.0**	**24.67**	
			S - 02	28.0	**11.0**	22.0		
		Study area - 6: Ashulia wetland	S - 01	46.0	27.0	**15.0**	**29.83**	
			S - 02	**51.0**	18.0	22.0		
		Study area - 7: Birulia wetland	S - 01	24.0	**30.0**	20.0	**22.17**	
			S - 02	22.0	**15.0**	22.0		

Table - 11: Turbidity Test Results Across Seven Study Areas

SL no.	Water quality parameters	Study area	Sample number	Value of three months (NTU)			Average value (NTU)	EQS
				October (2020)	November (2020)	December (2020)		
06.	**Turbidity**	Study area - 1: Dhanmondi Lake	S - 01	**4.91**	25.7	8.91	**14.07**	**10 NTU**
			S - 02	7.30	**32.4**	5.21		
		Study area - 2: Gulshan-Baridhara Lake	S - 01	42.2	45.6	**32.6**	**41.13**	
			S - 02	37.5	**48.8**	40.1		
		Study area - 3: Hatirjheel Lake	S - 01	**26.4**	64.2	28.4	**40.77**	
			S - 02	30.0	**69.0**	26.6		
		Study area - 4: Ramna Lake	S - 01	**5.70**	**18.7**	18.6	**14.42**	
			S - 02	10.5	14.8	18.2		
		Study area - 5: Bottola Dia Bari Lake	S - 01	**12.5**	41.0	58.6	**40.88**	
			S - 02	15.2	**62.0**	56.0		
		Study area - 6: Ashulia wetland	S - 01	**7.28**	60.5	62.0	**44.30**	
			S - 02	12.0	**63.2**	60.8		
		Study area - 7: Birulia wetland	S - 01	35.2	37.4	58.3	**43.67**	
			S - 02	39.3	**33.2**	**58.6**		

Table - 12: Nitrate-Nitrogen (NO3-N) Test Results Across Seven Study Areas

SL no.	Water quality parameters	Study area	Sample number	Value of three months (mg/L) October (2020)	November (2020)	December (2020)	Average value (mg/L)	EQS
07.	**Nitrate-Nitrogen (NO3-N)**	Study area - 1: Dhanmondi Lake	S - 01	0.40	0.80	1.00	**0.73**	**10 mg/L**
			S - 02	**0.30**	0.70	**1.20**		
		Study area - 2: Gulshan-Baridhara Lake	S - 01	1.40	1.40	**1.70**	**1.33**	
			S - 02	1.40	1.10	**1.00**		
		Study area - 3: Hatirjheel Lake	S - 01	**1.50**	**0.70**	0.90	**1.10**	
			S - 02	1.40	1.00	1.10		
		Study area - 4: Ramna Lake	S - 01	0.80	**0.60**	0.80	**0.82**	
			S - 02	0.70	**1.00**	**1.00**		
		Study area - 5: Bottola Dia Bari Lake	S - 01	0.40	1.00	**1.40**	**0.85**	
			S - 02	**0.30**	1.20	0.80		
		Study area - 6: Ashulia wetland	S - 01	**1.00**	0.40	0.80	**0.63**	
			S - 02	0.80	**0.20**	0.60		
		Study area - 7: Birulia wetland	S - 01	0.80	**0.40**	**1.70**	**0.98**	
			S - 02	0.90	0.70	1.40		

Table - 13: Phosphate (PO4) Test Results Across Seven Study Areas

SL no.	Water quality parameters	Study area	Sample number	Value of three months (mg/L)			Average value (mg/L)	EQS
				October (2020)	November (2020)	December (2020)		
08.	**Phosphate (PO_4)**	Study area - 1: Dhanmondi Lake	S - 01	**5.10**	1.50	4.90	**3.75**	**6 mg/L**
			S - 02	4.80	**1.20**	5.00		
		Study area - 2: Gulshan-Baridhara Lake	S - 01	8.40	0.90	4.40	**4.57**	
			S - 02	**8.70**	**0.70**	4.30		
		Study area - 3: Hatirjheel Lake	S - 01	**18.1**	13.4	**8.00**	**13.50**	
			S - 02	17.5	15.2	8.80		
		Study area - 4: Ramna Lake	S - 01	**0.10**	0.80	4.80	**1.90**	
			S - 02	**0.10**	0.70	**4.90**		
		Study area - 5: Bottola Dia Bari Lake	S - 01	**7.60**	**3.00**	6.00	**5.47**	
			S - 02	6.80	3.20	6.20		
		Study area - 6: Ashulia wetland	S - 01	0.70	**0.00**	4.20	**1.88**	
			S - 02	0.50	0.20	**5.70**		
		Study area - 7: Birulia wetland	S - 01	3.40	**0.30**	6.30	**3.47**	
			S - 02	3.80	0.50	**6.50**		

Table - 14: Total Dissolved Solid (TDS) Test Results Across Seven Study Areas

SL no.	Water quality parameters	Study area	Sample number	Value of three months (mg/L)			Average value (mg/L)	EQS
				October (2020)	November (2020)	December (2020)		
09.	**Total Dissolved Solid (TDS)**	Study area - 1: Dhanmondi Lake	S - 01	**149.5**	137.7	**125.0**	**136.97**	**2100 mg/L**
			S - 02	145.3	137.3	127.0		
		Study area - 2: Gulshan-Baridhara Lake	S - 01	196.1	213.0	**259.0**	**219.92**	
			S - 02	**186.2**	212.2	253.0		
		Study area - 3: Hatirjheel Lake	S - 01	251.0	220.0	**273.0**	**246.00**	
			S - 02	246.0	**213.0**	**273.0**		
		Study area - 4: Ramna Lake	S - 01	**73.0**	78.70	76.0	**76.63**	
			S - 02	**79.0**	78.10	75.0		
		Study area - 5: Bottola Dia Bari Lake	S - 01	150.0	152.3	161.0	**154.75**	
			S - 02	**148.0**	154.2	**163.0**		
		Study area - 6: Ashulia wetland	S - 01	**71.0**	80.60	**320.0**	**158.07**	
			S - 02	76.0	82.80	318.0		
		Study area - 7: Birulia wetland	S - 01	70.0	81.0	265.0	**139.20**	
			S - 02	**68.0**	83.20	**268.0**		

Table - 15: Electrical Conductivity (EC) Test Results Across Seven Study Areas

SL no.	Water quality parameters	Study area	Sample number	Value of three months (umohos/cm)			Average value (umohos/cm)	EQS
				October (2020)	November (2020)	December (2020)		
10.	Electrical Conductivity (EC)	Study area - 1: Dhanmondi Lake	S - 01	279.0	279.0	233.0	264.00	1200 umohos/ cm
			S - 02	283.0	277.0	233.0		
		Study area - 2: Gulshan-Baridhara Lake	S - 01	363.0	427.0	462.0	416.55	
			S - 02	359.0	427.3	461.0		
		Study area - 3: Hatirjheel Lake	S - 01	463.0	450.0	476.0	463.17	
			S - 02	467.0	447.0	476.0		
		Study area - 4: Ramna Lake	S - 01	137.0	157.7	144.0	147.30	
			S - 02	142.0	159.1	144.0		
		Study area - 5: Bottola Dia Bari Lake	S - 01	280.0	304.0	295.0	295.33	
			S - 02	287.0	311.0	295.0		
		Study area - 6: Ashulia wetland	S - 01	132.0	165.0	565.0	287.30	
			S - 02	128.0	167.8	566.0		
		Study area - 7: Birulia wetland	S - 01	132.0	167.5	472.0	256.77	
			S - 02	129.0	169.1	471.0		

(Source: Tested and checked in DoE Laboratory by collecting samples from study areas)

Table - 16: Results of Average and Standard Deviation of Selected Water Parameters Across Seven Study Areas

Urban Wetland	Temp		pH		DO		BOD		COD	
	Avg	St. Dev	Avg	St. Dev	Avg	St. Dev	Avg	St. Dev	Avg	St. Dev
SA1: DL	19.983	2.931	7.290	0.281	7.033	2.190	10.083	2.577	33.167	12.497
SA2: GBL	20.583	2.303	7.247	0.176	3.033	2.588	26.417	3.774	116.500	52.034
SA3: HL	20.067	3.128	7.335	0.065	5.167	3.204	27.033	15.116	86.667	54.173
SA4: RL	20.350	2.182	7.368	0.253	8.217	1.528	6.633	3.125	64.667	59.018
SA5: DBBL	20.283	2.297	7.553	0.248	6.767	3.077	7.133	5.369	24.667	8.664
SA6: AUW	20.383	2.587	7.390	0.108	5.633	1.837	5.667	3.724	29.833	15.092
SA7: BUW	20.617	2.606	7.332	0.104	5.117	2.478	10.467	7.901	22.167	4.916

Table - 17: Results of Average and Standard Deviation of Selected Water Parameters Across Seven Study Areas (contd.)

Urban Wetland	Turbidity		Nitrate		Phosphate		TDS		EC	
	Avg	St. Dev	Avg	St. Dev	Avg	St. Dev	Avg	St. Dev	Avg	St. Dev
SA1: DL	14.072	11.884	0.733	0.344	3.750	1.864	136.967	9.692	264.000	24.091
SA2: GBL	41.133	5.778	1.333	0.250	4.567	3.472	219.917	29.777	416.550	45.707
SA3: HL	40.767	20.111	1.100	0.303	13.500	4.299	246.000	25.487	463.167	12.481
SA4: RL	14.417	5.322	0.817	0.160	1.900	2.304	76.633	2.379	147.300	8.982
SA5: DBBL	40.883	22.152	0.850	0.437	5.467	1.917	154.750	6.026	295.333	11.183
SA6: AUW	44.297	26.903	0.633	0.294	1.883	2.434	158.067	124.726	287.300	216.113
SA7: BUW	43.667	11.634	0.983	0.479	3.467	2.690	139.200	98.789	256.767	167.192

Appendix - 4

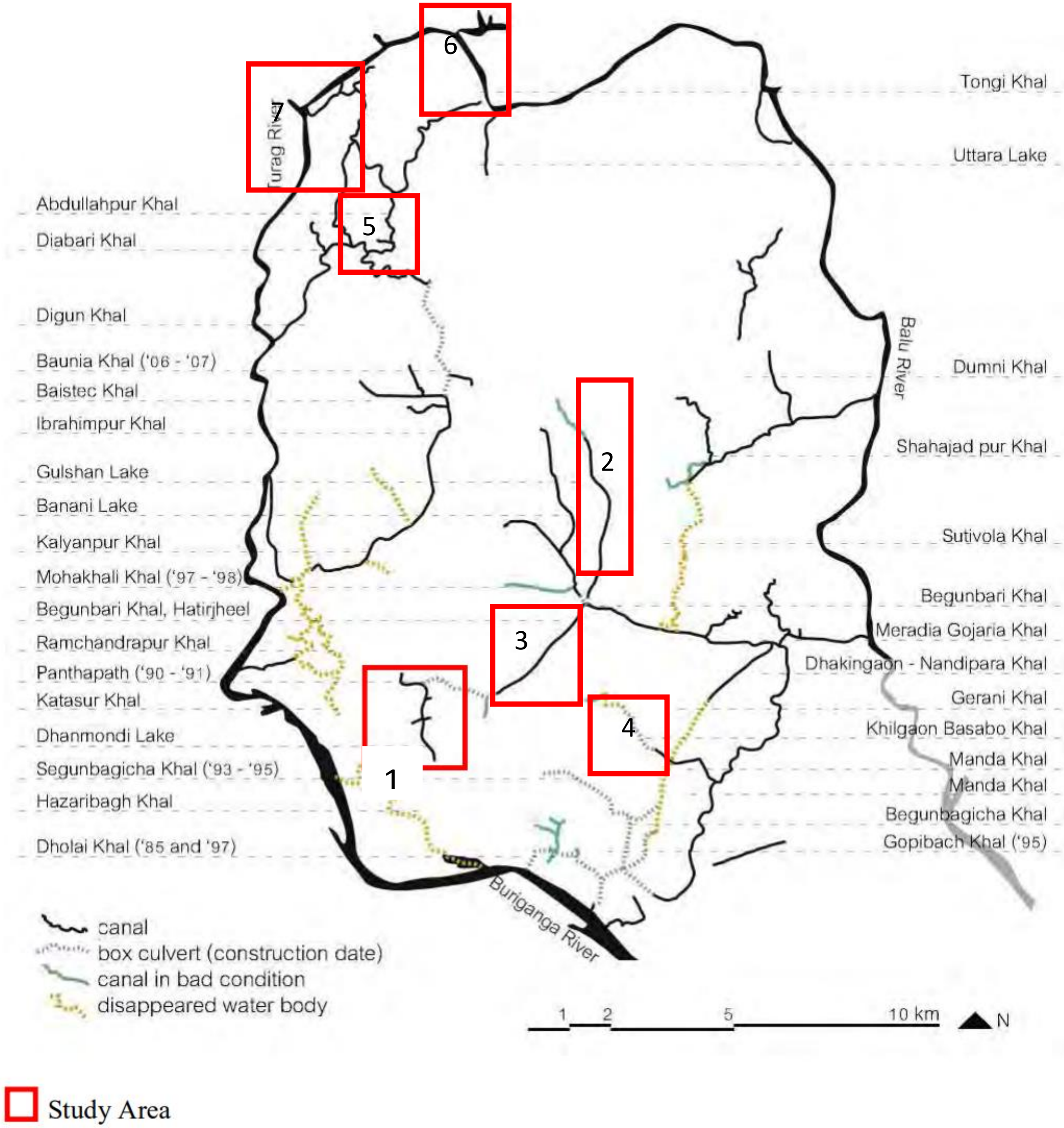
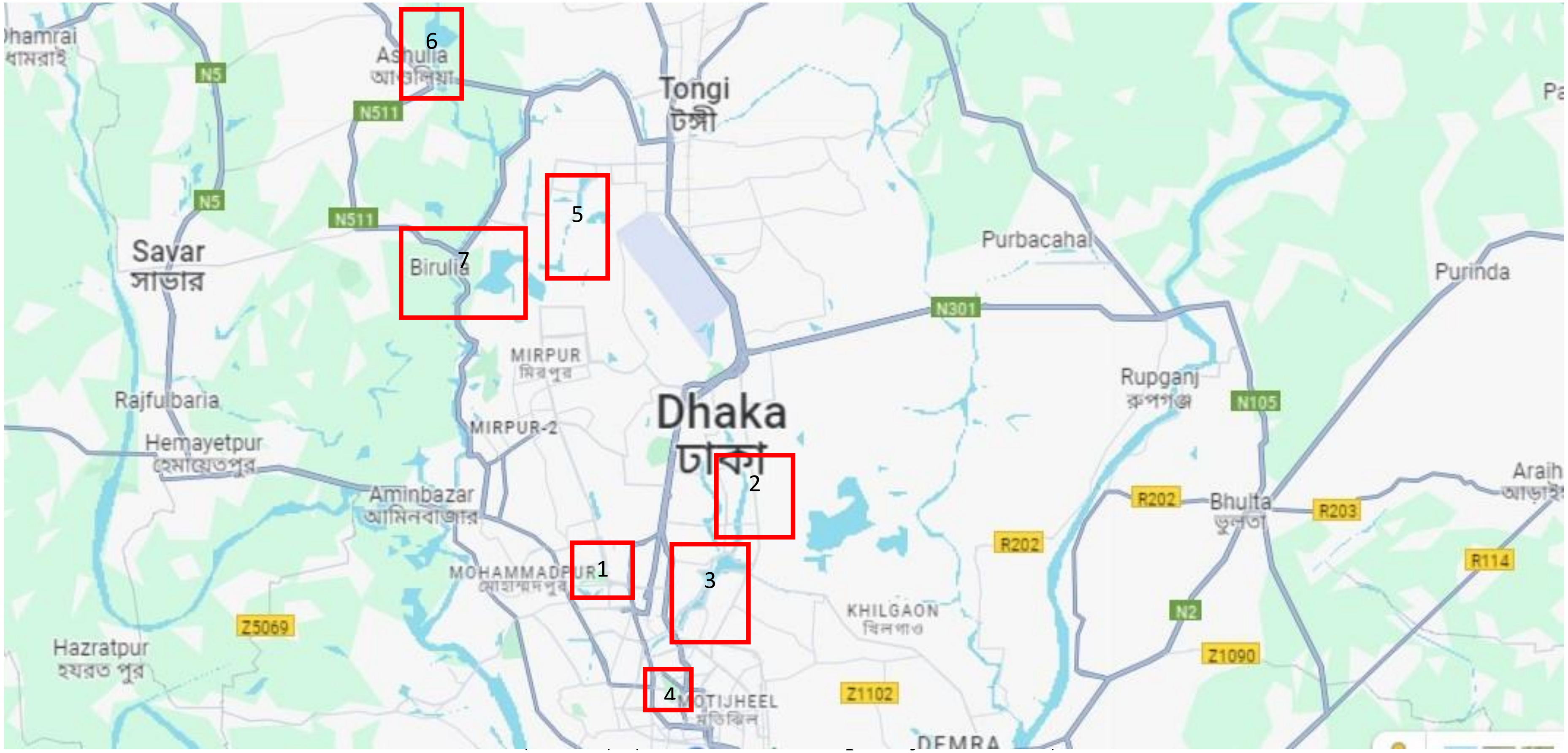


Figure - 08: Location of Study Area and other existing urban wetlands within Dhaka city (Source: Sharmeen, 2014) (Edited and developed by the author)



Study area

Figure - 09: Location of Study area and other existing urban wetlands within Dhaka city (Source: Google Image, 2024) (Edited and developed by the author)