2023 project report

Title: Developing Citizen-Relevant Water Quality Criteria for Urban Lakes in Bengaluru

Funded by Bengaluru Sustainability Forum (BSF) Small Grants

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Introduction

The project was designed to establish a working definition of clean and healthy urban lakes, with corresponding water quality criteria and targets, to ensure the sustainability of community needs and urban biodiversity.

The outcome of the project will be:

- Tools to develop a flexible and evolving definition of what constitutes a clean lake and manage it sustainably. This is be achieved by developing **Water Quality Criteria** (WQC) for urban lakes to support different lake uses.
- Easy to use monitoring tools for citizens to reliably track the water quality and ecological health of the lake over time by developing **biological indicators (bioindicators) list** for urban lakes to use for lake water quality monitoring.

The project would help in capacity building of citizens though workshops and lake festivals organized by citizen groups and NGOs, allowing for better water quality data collection through improved understanding. The use of **bioindicators** would help in spreading awareness and improving community engagement for the conservation of biodiversity at the lake and also understand how different people view and value the lake. This would also give a platform for different stakeholders to state their needs from the lake and allow for an inclusive approach to lake management.

This project is collaborating with the Lake Health Index (LHI) project through data exchange. The water chemistry data collected by the LHI survey (Primary users) is being used as indicative sample collection locations for the Pro Users or researchers for robust and accurate sampling for water quality analysis. The water quality, bioindicator and lake water quality perception data collected by WQC in turn is being shared with LHI for recalibrating the weightage given to the indicative parameters in LHI. This will help in creating a more accurate and robust dynamic lake health index. LHI's awareness and converting of Primary users to Pro user with a better understanding of lake health can aid to have more inclusive discussions and approaches to lake management (Figure 1).

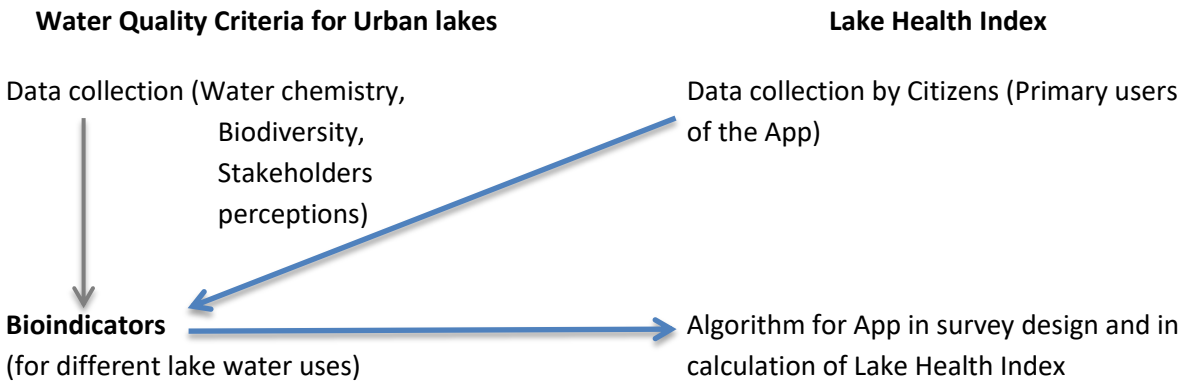


Figure 1: Flow chart for work collaboration between Water Quality Criteria (WQC) and Lake Health Index (LHI) projects

Process Documentation of Data collection

Lake selection

11 lakes within BBMP administrative boundary were selected to represent different levels of water pollution in Bengaluru for the development of the Water Quality Criteria (WQC) (Table 1). Factors used for lake selection are catchment population density, Settling Tank and Constructed Wetland presence/absence in the lake, Sewage Treatment Plant (STP) present for the lake, or if STP infrastructure is absent. For the selection process, existing data from online public platforms and government documents were used followed by ground truthing.

Table 1: 11 lakes selected for the project

Intervention	Lakes name (Code)	Catchment population density (ppl/km^2)	Lake/Catchment area ratio	Lake features
Diversion channels at inlets (DC)	Doddakallasandra (DD)	7844	0.04	CW-P, ST-A, I-P
	Devarabisanahalli (DE)	3621	0.04	CW-P, ST-A, I-P
	Agrahara (AG)	2342	0.05	CW-P, ST-A, I-P
	Chikka Kudlu (CK)	8022	0.04	CW-P, ST-A, I-P
No interventions (NI)	Hoodi (HD)	7386	0.03	CW-A, ST-A, I-A
	Narasappanahalli (NR)	11688	0.06	CW-A, ST-A, I-A
Lakes receiving STP discharging treated effluents and inflows from storm water channels (STP)	Sarrakki (SA)	25768	0.12	CW-P, ST-A, I-P
	Dodda Bommasandra (DM)	6798	0.04	CW-P, ST-A, I-P
	Deepanjalinagara* (DR)	26936	0.02	CW-A, ST-A, I-A
	Hulimavu(HU)	6570	0.11	CW-A, ST-A, I-A
	Jakkur (JK)	4216	0.04	CW-P, ST-P, I-P

Key: CW- Constructed Wetland, ST- Settling Tank, I-Island; A-Absent, P-Present.
*also known as Deevaligeramnahalli Lake

For identifying suitable lakes for the project, existing available documents and QGIS (a free GIS app) were used to prepare a lake list for ground truthing. Ground truthing was carried out to ensure accessibility of sampling points at the shortlisted lakes. A field assistant was hired to aid in conducting field surveys of lakes.

Ground truthing was carried out between September 2021 to December 2021. A total of 51 lakes were visited and based on these ground visits and details from Rashmi Kulranjan's ground truthing of other lakes (a PhD student working on hydrological linkages of Bengaluru's lakes at ATREE), 20 lakes were identified to conduct water sample and plant specimen collection and for permission application to the Bruhat Bengaluru Mahanagara Pallike (BBMP) Lake Department in January 2022. The list was revised to 11 lakes (Map 1) and permissions for carrying out water and plant sample collection at the lakes were acquired from the BBMP Lake Department.

Map 1: Final selected lakes in Bengaluru city.

The list of selected lakes was reduced from 20 lakes to 11 as per the following reasons:

i. The selection process was revised after ground truthing, as it was observed that the variation in the lake water quality and management approaches could be captured in 20 lakes or less.

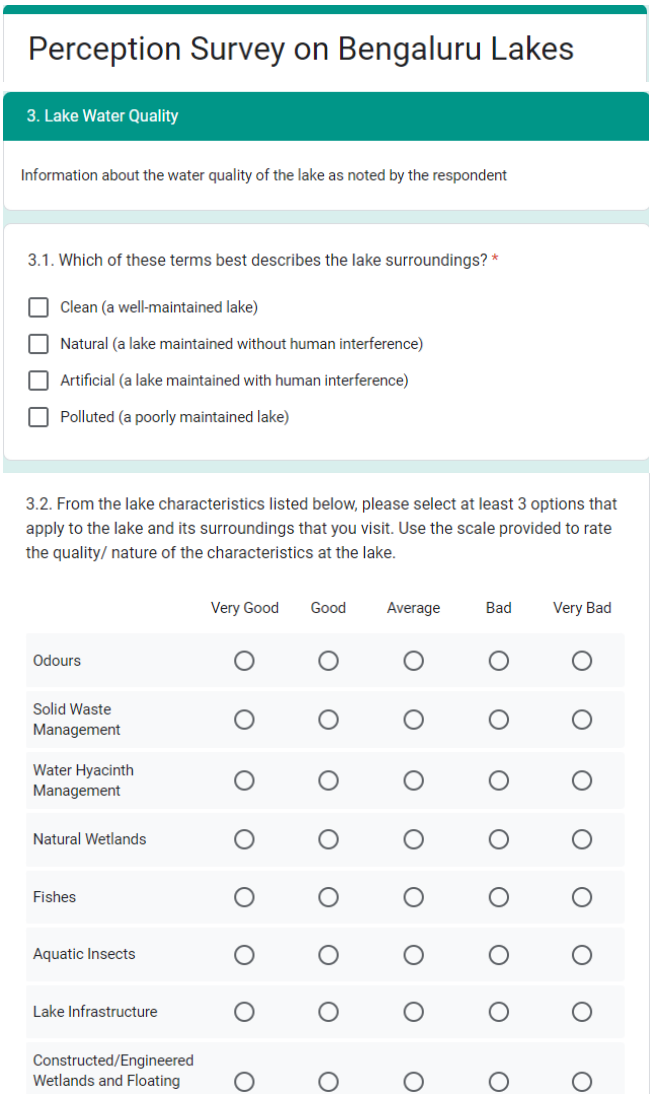
ii. During the BBMP Lake Department permission process, it was informed that 20 lakes could not be included in the application process and should be reduced to 10 lakes. No clear explanation was provided as to why the stated number was given or how the number was decided upon. By collaborating with Rashmi Kulranjan, a PhD student from ATREE, the lake list was revised to ensure that the number of lakes approved for water sample collection was 10. The final lake number is 11 by collaborating with Rashmi by including lakes under her work permission to collect the necessary water samples.

Online and in lake surveys

The questionnaire forms for collecting details on the selected lakes' aspects such as water quality perception, economic activities being carried out there and for the rejuvenation history were prepared by December 2020 (Photo 1). Trial runs with the designed questionnaires for lake perception was conducted with a small group of participants and necessary changes were made based on the feedback received by August 2021. Following this, finalization of the questionnaires for an online survey about different lake users' perception and collecting basic information on lake management from the lake groups of the selected lakes was carried out in 2022.

Due to the COVID 19 related lock downs and the restrictions on the opening of public spaces such as lakes, the survey forms were shared with lake groups on their online platforms for response collection. Not all lakes have lake groups, so this was possible only for some of the lakes. Out of the 11 lakes, 5 lakes have citizen's lake groups, who were contacted for their participation in surveys in January 2022. The perception survey and the lake rejuvenation history survey forms were circulated with lake groups via their social platforms to collect responses in January 2022 and the online survey was kept open till August 2022. For lake rejuvenation history survey, out of the 5 lake groups, 4 lake groups have responded through Google Survey forms, i.e. Doddakallasandra, Sarrakki, Hulimavu and Jakkur. Similarly, for the lake users' perception survey, out of the 5 lakes with online lake groups, responses from 4

lakes have been received via responses from Google Survey forms. Between February to August 2022 economic surveys and a few additional in-person perception surveys were carried out at the selected lakes.



Perception Survey on Bengaluru Lakes

3. Lake Water Quality

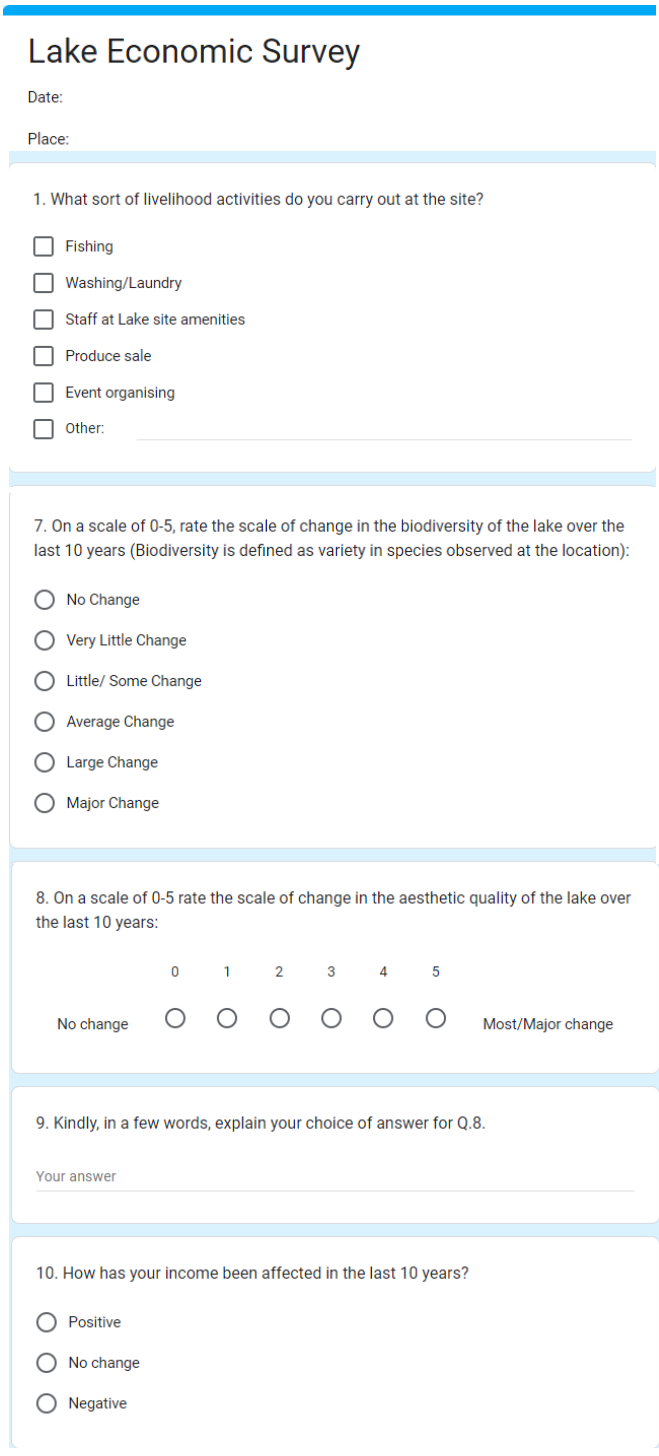
Information about the water quality of the lake as noted by the respondent

3.1. Which of these terms best describes the lake surroundings? *

- [ ] Clean (a well-maintained lake)
- [ ] Natural (a lake maintained without human interference)
- [ ] Artificial (a lake maintained with human interference)
- [ ] Polluted (a poorly maintained lake)

3.2. From the lake characteristics listed below, please select at least 3 options that apply to the lake and its surroundings that you visit. Use the scale provided to rate the quality/ nature of the characteristics at the lake.

	Very Good	Good	Average	Bad	Very Bad
Odours	○	○	○	○	○
Solid Waste Management	○	○	○	○	○
Water Hyacinth Management	○	○	○	○	○
Natural Wetlands	○	○	○	○	○
Fishes	○	○	○	○	○
Aquatic Insects	○	○	○	○	○
Lake Infrastructure	○	○	○	○	○
Constructed/Engineered Wetlands and Floating	○	○	○	○	○



Lake Economic Survey

Date:

Place:

1. What sort of livelihood activities do you carry out at the site?

- [ ] Fishing
- [ ] Washing/Laundry
- [ ] Staff at Lake site amenities
- [ ] Produce sale
- [ ] Event organising
- [ ] Other:

7. On a scale of 0-5, rate the scale of change in the biodiversity of the lake over the last 10 years (Biodiversity is defined as variety in species observed at the location):

- ○ No Change
- ○ Very Little Change
- ○ Little/ Some Change
- ○ Average Change
- ○ Large Change
- ○ Major Change

8. On a scale of 0-5 rate the scale of change in the aesthetic quality of the lake over the last 10 years:

	0	1	2	3	4	5	
No change	○	○	○	○	○	○	Most/Major change

9. Kindly, in a few words, explain your choice of answer for Q.8.

Your answer

10. How has your income been affected in the last 10 years?

- ○ Positive
- ○ No change
- ○ Negative

Photo 1: Left-Screen shots of the lake water quality perception survey .Right- Screen shots of the lake based economic activities survey.

Water sample physical and chemical analysis

Following the BBMP Lake Department approval, water sample collection along with aquatic bird and aquatic plant surveys were planned for January 2022, which got delayed due to sudden rain events in Bengaluru city during that time. The scheduled field work could not be carried out during the rain events or immediately after the rain events as it is advised not to be done by expert suggestions and data collection methodology. The field work was started from February 2022 and carried on till August 2022. Water quality analysis was completed by September 2022.

For physical and chemical analysis of water samples collected from the lakes, water quality probes, standard methods or appropriate testing kits by Merck were used. Parameters measured included pH, Temperature, Dissolved Oxygen, Total Suspended Solids, Nutrients (Nitrates, Ammonium & Phosphates, Total Nitrogen & Total Phosphorus), Chemical Oxygen Demand, Biological Oxygen Demand, Faecal Coliform and Chlorophyll-a.

Photo 2: Measurement of pH, Electrical Conductivity and Dissolved oxygen using YSI probes at Chikka Kudlu outlet, 04-05-2022. Photo credits: Monika KM

Photo 3: Water sample collection at Agrahara Lake, 03-06-2022. Photo credits: Rashmi Kulranjan.

Biological indicator surveys

Field testing for aquatic bird and aquatic plant surveys methods were carried out in 2021 across several months with the help of interns and members from different lake groups. The finalized methods were then used to carry out quantification of aquatic bird and aquatic plant abundance and diversity at the selected lakes.

Abundance and diversity of aquatic plants growing in the water and along the shore line was estimated at each lake by carrying out plant surveys over multiple 100m stretches spread along the perimeter of each lake's shore. Similarly, aquatic bird diversity and abundance was carried out using multiple points at each lake to note down the birds observed at the lake. Two interns from Bangalore University had joined to carry out the biological indicator (bioindicator) surveys.

Photo 4: Conducting out plant survey at Deepanjalinagara Lake, 04-05-2022. Photo credit: Rakesh Kumar.

Data analysis and dissemination

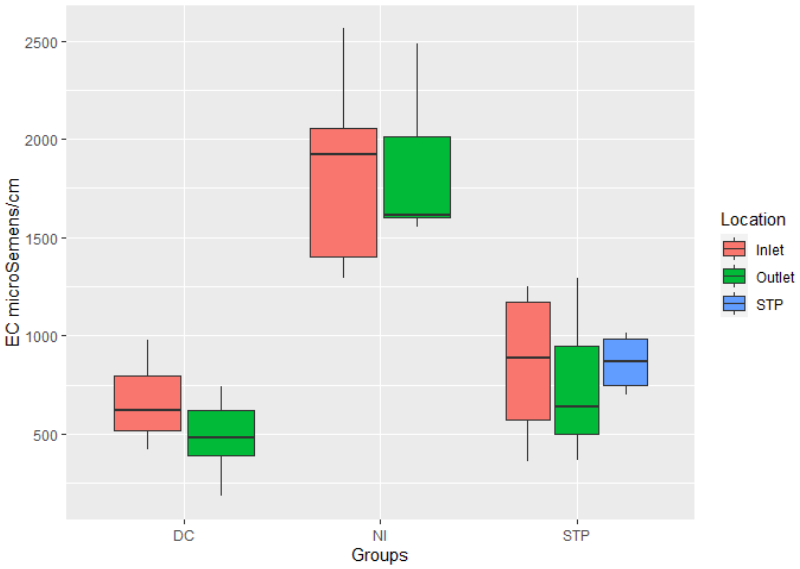
Disclaimer: The findings and details discussed below are based on ongoing scientific research that is currently under the publication process. As the research is still in the review and validation stages, we kindly request that readers refrain from using this information without prior permission from the project team. Using preliminary findings without proper

attribution or prior consent may lead to misinterpretation of the results, and we aim to present the final, peer-reviewed results when they become available. We appreciate your understanding and respect for the scientific process.

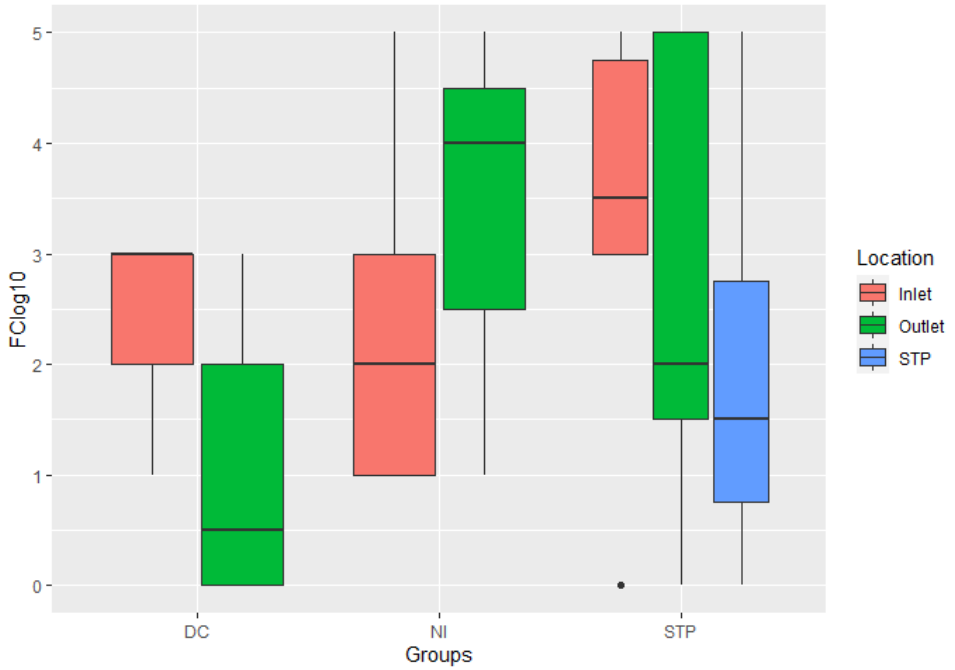
The collected data is undergoing analysis for publication in peer-reviewed journals. Summarized documents, highlighting the research findings, are also in preparation for review by lake groups and government agencies. Once accepted, these publications will be shared with the BSF team for public access on the website. These research papers align closely with the project's key objectives. Future documents, utilizing the same data, will also be shared with the BSF team for public dissemination on the website.

The synthesized data is undergoing discussion with lake groups to incorporate their feedback. It will subsequently be made available on online lake monitoring platforms, including the LHI project. Ongoing discussions with the LHI team involve integrating data and insights from both the WQC and LHI projects into their respective future activities. Specific details regarding this integration are currently being finalized.

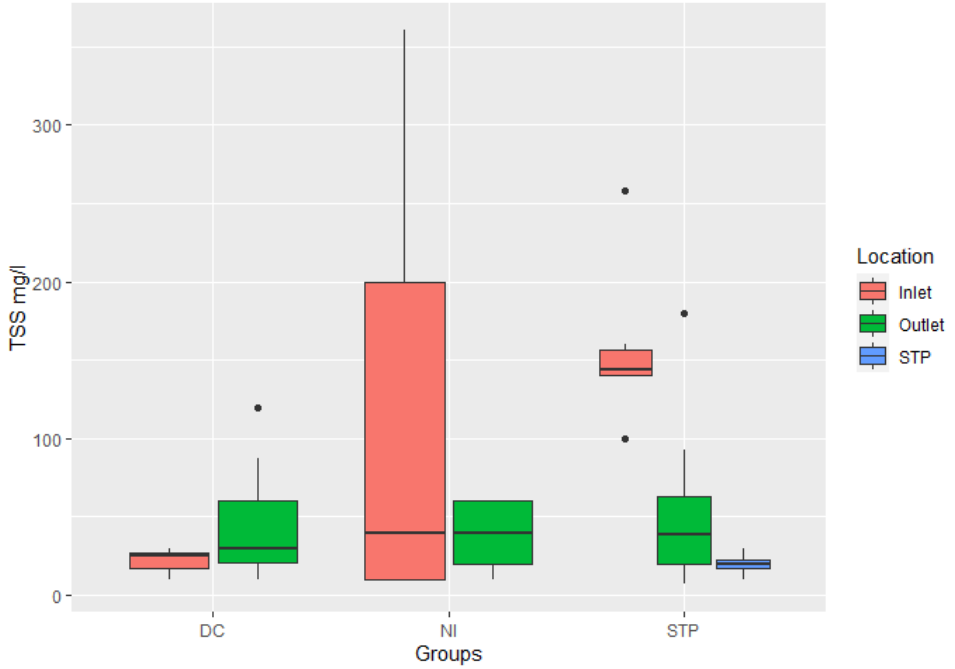
The some of the preliminary data in terms of lake water quality, and aquatic plant and bird are as follows. For water quality, below is the summary of the lake water quality data collected for a number of parameters:



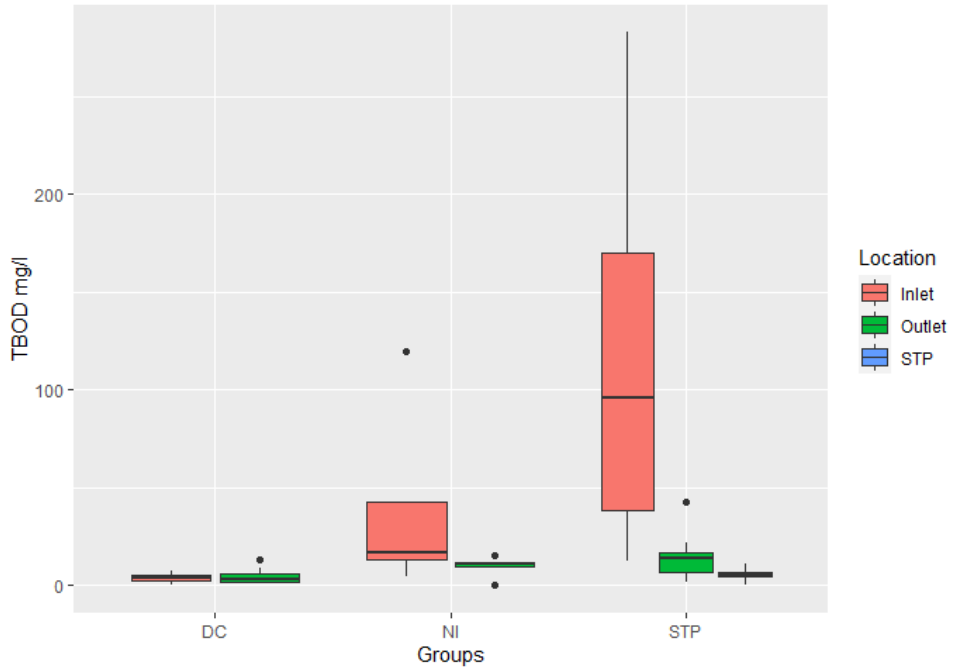
Graph 1: Graph showing the inlets and outlets Electrical Conductivity (EC) concentrations for the different intervention categories. Key: DC- Diversion Channels, NI- No Interventions, STP- Receiving STP treated effluents and storm drain inflow



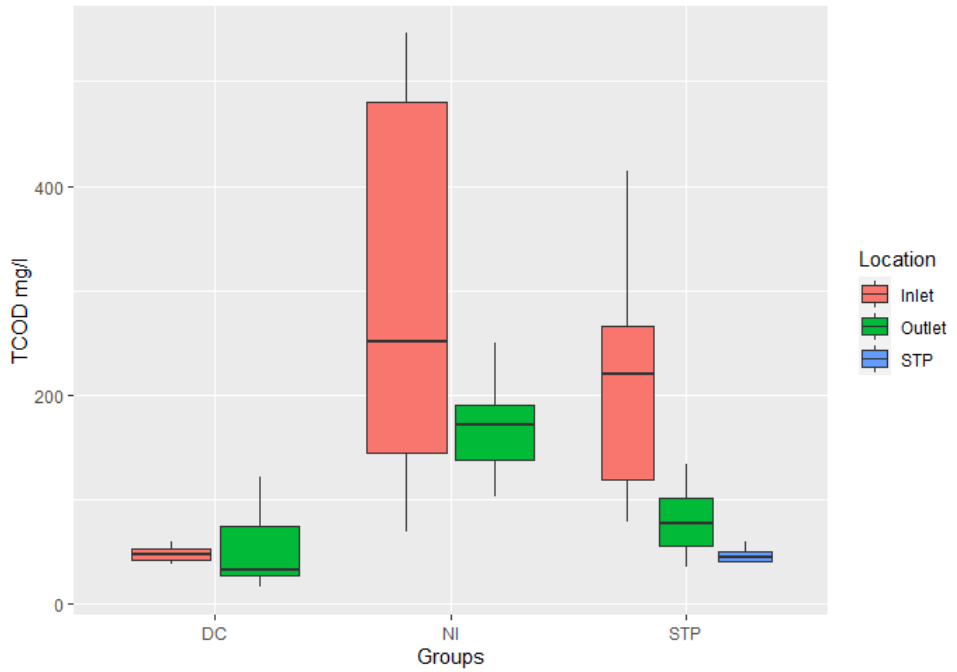
Graph 2: Faecal Coliform (FC)Log values for inlets and outlets for lakes with different interventions. Key: DC- Diversion Channels, NI- No Interventions, STP- Receiving STP treated effluents and storm drain inflow



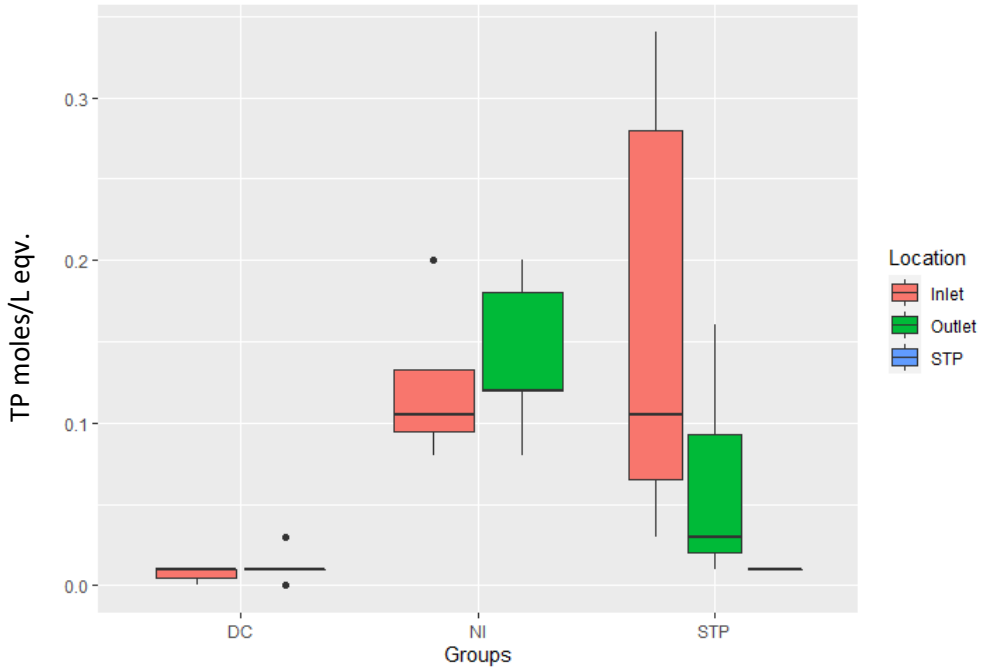
Graph 3: Total Suspended Solids (TSS) values for inlets and outlets for lakes under different interventions. Key: DC- Diversion Channels, NI- No Interventions, STP- Receiving STP treated effluents and storm drain inflow



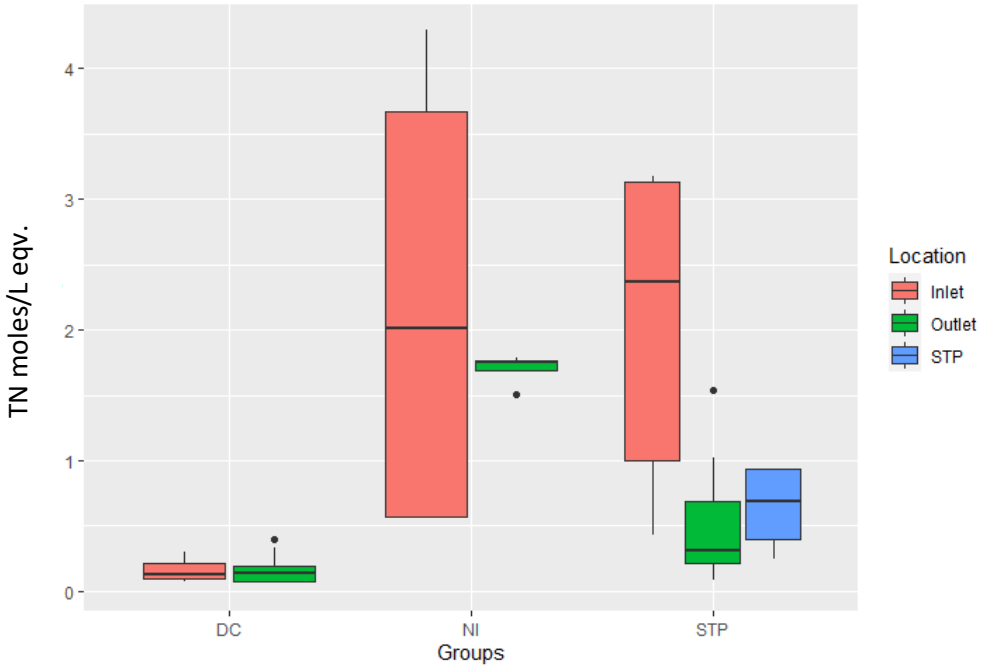
Graph 4: Total Biological Oxygen Demand (TBOD) values for inlets and outlets with different intervention approaches. Key: DC- Diversion Channels, NI- No Interventions, STP- Receiving STP treated effluents and storm drain inflow



Graph 5: Total Chemical Oxygen Demand (TCOD) values for inlets and outlets of lakes with different interventions. Key: DC- Diversion Channels, NI- No Interventions, STP- Receiving STP treated effluents and storm drain inflow



Graph 6: Total Phosphorus (TP) values for lake inlets and outlets for different intervention groups. Key: DC- Diversion Channels, NI- No Interventions, STP- Receiving STP treated effluents and storm drain inflow

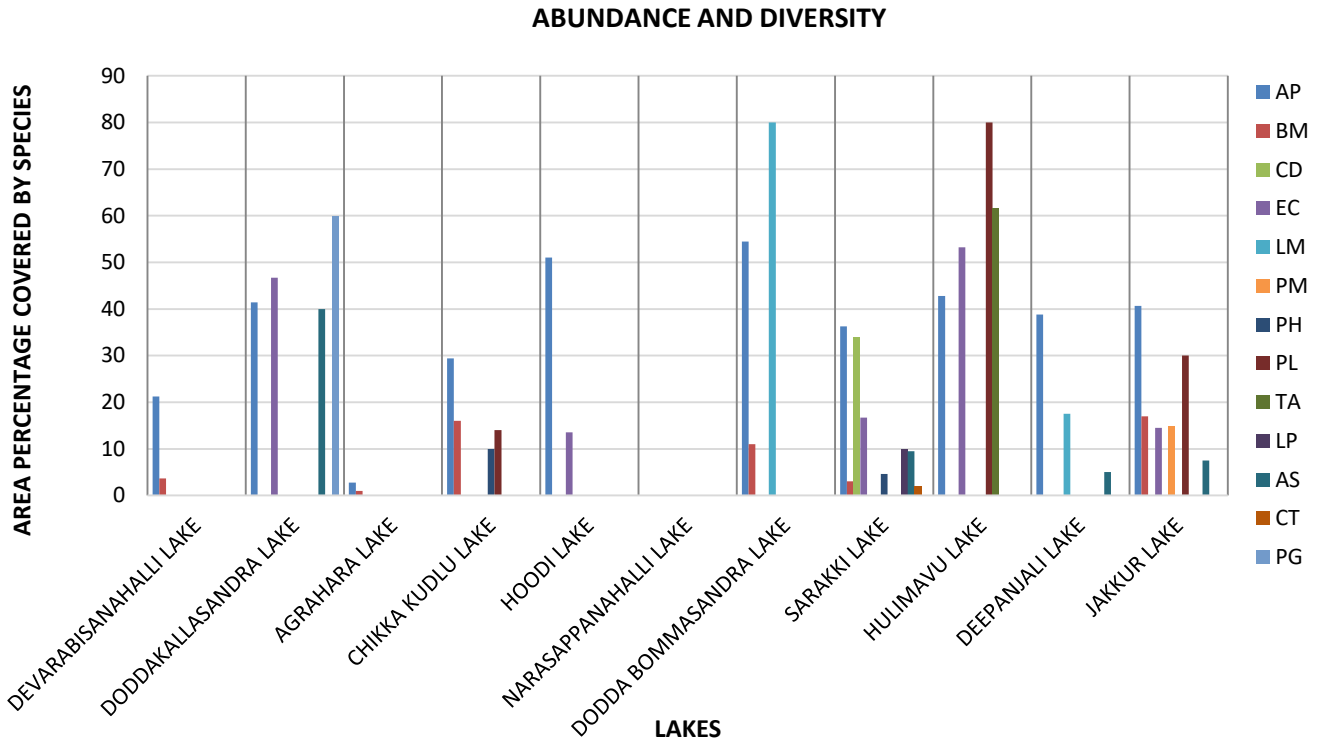


Graph 7: Total Nitrogen (TN) values for lakes with different interventions, inlet and outlet values presented. Key: DC- Diversion Channels, NI- No Interventions, STP- Receiving STP treated effluents and storm drain inflow

For aquatic plants surveyed, 13 species were identified, details of which are mentioned below (Table 2, graph 8).

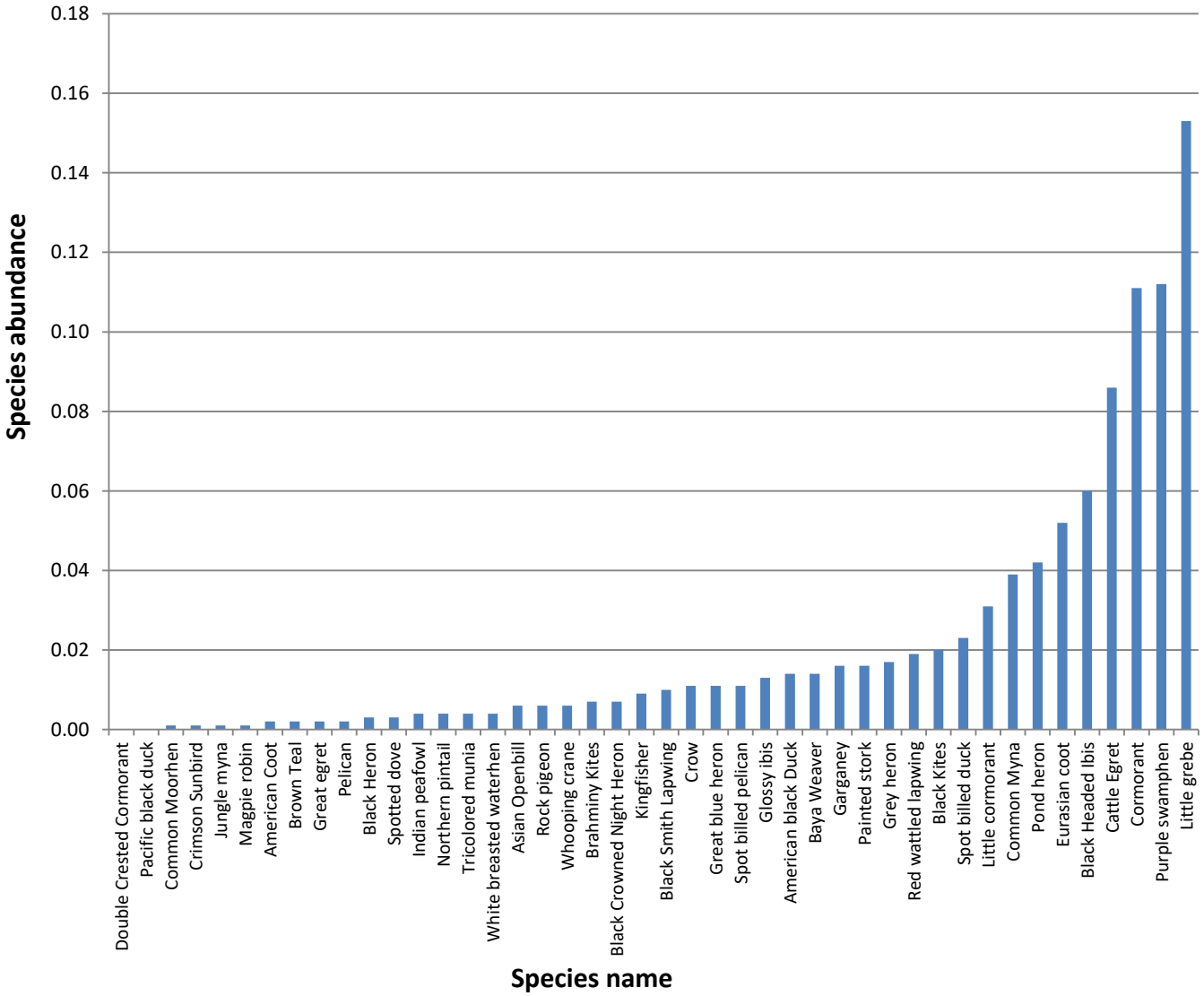
Table 2: Aquatic plants identified during the survey period

No.	Local name	*Scientific name*	Code	Native/ Invasive	Use	Habitat
1	Alligator weed	*Alternanthera philoxeroides*	AP	Invasive	Food, medicine	Aquatic and terrestrial
2	Buffalo grass	*Brachiaria mutica*	BM	Invasive	Medicine, Fodder	Aquatic
3	Scutch grass	*Cynodon dactylon*	CD	Native	Medicine	Terrestrial
4	Water hyacinth	*Eichhornia crassipes*	EC	Invasive	Fodder, biofuels, evapotranspiration(negative)	Aquatic
5	Duck weed	*Lemna minor*	LM	Native	Food, medicine	Aquatic
6	Guinea Grass	*Panicum maximum*	PM	Invasive	Food, medicine	Semi-aquatic
7	Congress grass	*Parthenium hysterophorus*	PH	Invasive	Medicine (negative)	Terrestrial
8	African Persicaria	*Persicaria lanigera*	PL	Invasive	Medicine	Semi-aquatic
9	Lesser Bulrush	*Typha angustifolia*	TA	Native	Food, medicine	Aquatic
10	Creeping Water Primrose	*Ludwigia prostrata*	LP	Native	Medicine (tentative)	Semi-aquatic
11	Sessile Joyweed	*Alternanthera s essilis*	AS	Native	Food, medicine	Terrestrial
12	Sickle Senna	*Cassia tora*	CT	Invasive	Medicine	Terrestrial
13	Dense flower Knotweed	*Polygonum glabrum*	PG	Native	Medicine	Aquatic



Graph 8: The abundance and diversity of aquatic plants across all lakes surveyed. For plant species key, please refer to table 3.

For bird survey, 44 species were identified. Out of this, 4 species were identified as near threatened (Black headed ibis, Spot billed pelican, Painted stork and Brown teal) and one species is endangered (Whooping crane) according to IUCN status (2009[1]) report. The most common bird species observed were the Little grebe, Purple Swamp hen, Cormorant and cattle egret species across all the lakes. Double crested cormorant and pacific black duck were detected least abundant across all the lakes (Graph 9).



Graph 9: Graph showing overall avian species abundance across all survey lakes

[1] IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2, www.iucnredlist.org.

Future scope of Phase 2 of the project

After sharing the WQC and bioindicators list with the stakeholders, the subsequent step would be **assist in development of local engagement and capacity building for data driven management of urban lakes**. This will be the next phase of the project, which would include the following:

1. Follow up with lake groups for improvement on the WQC and bioindicators list through workshops for future scenarios. These workshops will help to identify possible future stakeholders of the lakes and their needs or possible uses of the lakes. For more clarity regarding the uses of the lakes, Focus Group Discussions will be carried out with different stakeholder groups for the identified lakes.
2. Sharing the WQC and Bioindicator list through public lake related events organized by the lake groups and NGOs.

Collaborating with lake groups and Friends of Lake to upload water quality and lake related data collected by citizen groups onto an online openly accessible platform such as the LHI project for public viewing. The impact would be that the data collected by the citizens would help better understand the existing conditions of the urban lakes and aid in more democratic approach of public space management.

Additional activities carried out apart from the initially discussed scope of the project

During the interim time before full work for the project could be started, two small projects were taken up to explore the lake water quality in the city. These were as follows -

1. HM analysis of lake water quality: In November and December 2020, along with an intern, 2 field trips were carried out for collecting lake water samples for a comparative study of the chemical quality between lakes in industrial area (Nelakadirenahalli Lake and Narasappanahalli Lake) and urban area (Kaikondranahalli Lake and Jakkur Lake) to study the heavy metal levels in the lake water. Initial observations indicated that all four lakes have heavy metals in them. Further review of literature is to be carried out to find possible sources of heavy metals for urban lakes and possible implications of heavy metals on urban lake ecology.

2. Investigating the sudden excessive growth of water hyacinth in Jakkur Lake observed in the 2021: In the starting of 2021, massive water hyacinth growth was observed at Jakkur Lake. Possible reasons for this massive growth were being explored with JalaPoshan, and preliminary investigation indicated to the absence of fishermen resulting in unmanaged growth of the plants leading to the blanketing of the water surface. Due to the COVID 19 pandemic, lake activities had been suspended, resulting in the loss of income for fishermen, which lead them to return back to their native.

Learnings and Experiences from the project

1. Plan better: Ensure adequate time is there in case activities identified require more time. During the water sample analysis, due to high standard deviations observed in the readings, multiple repeat tests of the water samples had to be carried out. This impacted subsequent activities as time and effort had to be diverted to ensure the water quality data was up to standard.
2. Keep small targets: Having multiple smaller targets with assigned time lines would have helped in meeting the deliverables. As the project involved collecting multiple types and formats of data, broad goals were kept. This later proved to be overwhelming and difficult to execute as each data type required a different method, which complicated the simultaneous execution of the methods.
3. Keep time aside for intern training: Certain amount of time is required for proper capacity building when hiring interns. And it is important to account for this to ensure realistic timelines are set. The interns who were a part of this project were motivated and inquisitive, which aided in the training period. However, the requisite skills are built only with repeated exposure and supervision, for which necessary time needs to be given. This ensures that when the interns begin to carry out data collection, the outcome of their hard work is reliable data which can be used for further analysis.
4. Keep time separately for engagement with stakeholders: Clearly demarcated time should be assigned to ensure engagement activities take place. Due to incorrect estimation of time during the planning stage and to the subsequent COVID 19 lock downs, the data products required for the stakeholder engagements are yet to be

ready. A more clearly demarcated time period for engagement might have been better for ensuring that the necessary engagements take place.

Notes which would be helpful for others working the space

1. Check online to see which all groups/institutes are working on the lake/area/subject that you want to work on and see how you can collaborate with them to reduce time/resource wastage.
2. Be realistic about what deliverables can be achieved in the allocated timeline. Best not to try to include your entire PhD work into the project as there may be multiple instances causing delays and missed targets.