ENRIVONMENTAL PERFORMANCE ASSESSEMENT ON FISHPONDS IN THE DEEP BAY OUTER RAMSAR AREA

For Rural Urban Lab
Balancing Ecological Sensitivity and Enhancing Experience

SNAPP Ocean Data Solutions Ltd.

Acknowledgements

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Project Description

The focus of this study is to research innovative solutions for wetland revitalization on sites located within Deep Bay, but that lie outside of the Ramsar protected area. This area includes fish ponds which are actively managed, some which are deteriorating, and some that have been in-filled.

The project will develop strategies that allow the public to engage in activities in the area without disturbing the natural habitat. The objective is to re-imagine how the wetlands can be used to balance conservation with new public attractors.

By working with key stakeholders including landowners and fish pond operators, the idea is to design and construct a pilot project that demonstrates the mutual benefit and cooperation needed to balance ecology with public engagement.

The project will support the continued and sustained ecological value of the site without its further degradation and raise public awareness on the future of Hong Kong's wetlands.

Project Objectives

Objective 1 - *To create a baseline study to understand current activities within the Deep Bay outer Ramsar site and indicate sites that are at risk of habitat loss and degradation.*

Objective 2 - *To design novel solutions that enable public benefits, without creating negative impacts to the wetland ecology, based on specific sites identified in the baseline study.*

Objective 3 - *To engage key stakeholders to provide feedback on the designs and identify selected projects for detailed development.*

Objective 4 - *To construct a design to demonstrate proof of concept in terms of programmatic, environmental, and structural performance.*

Objective 5 - *To raise public awareness of the balance between conservation and how sites of ecological value can become public attractors.*

Contents

About **SNAPP**

Our services integrates cutting-edge robotics, data science platforms, and scientific community expertise, to provide actionable insights for data-driven decision making.

Our team is committed to developing projects that foreground ecosystem services and ecological interactions. We recognize that data and technology can enhance collaborations across stakeholders of all backgrounds and expertise. Together we can craft the path towards a more habitable environment for all.

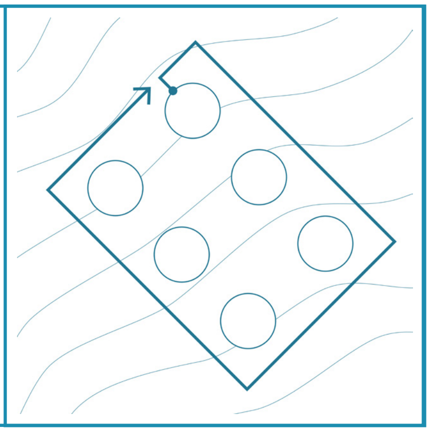
We are geared towards supporting innovative projects, through the work of our dedicated team of engineers and growing network of scientific partners.

Our **Services**

Coasts are dangerous and challenging environments to work with. This causes data gaps in monitoring, resulting in ineffective and inadequate detection.

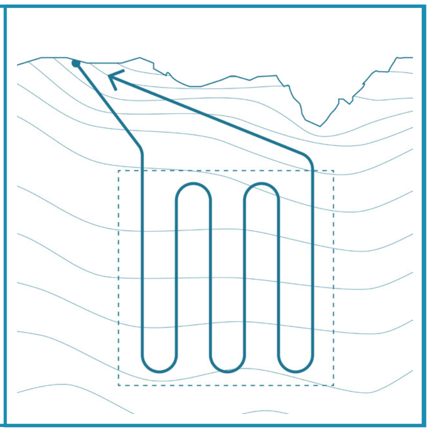
Aquaculture Support

Long-term monitoring for daily decision making



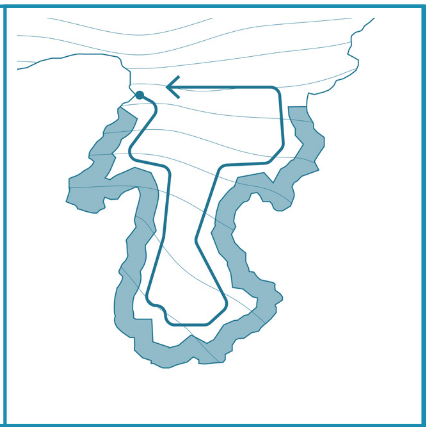
Research & Surveillance

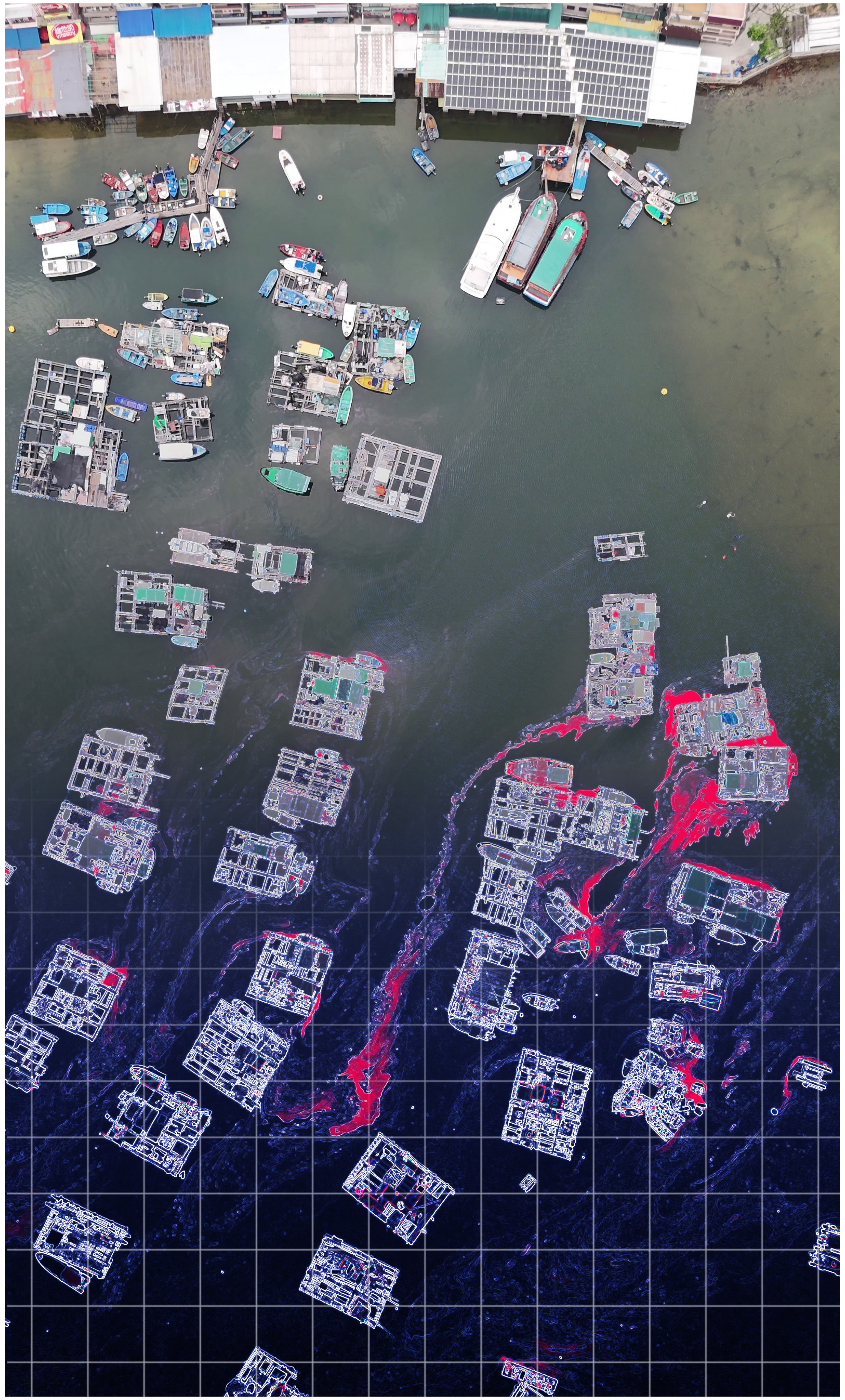
Frequent surveys for insights



Nature-based Solutions & Impact Assessment

Project-based monitoring to project into the future





Join our mission

A more habitable environment for all

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Background

SNAPP Ocean Data Solutions Ltd. (SNAPP) is assisting Rural Urban Lab (RUL) in their baseline study of fishponds through a data-driven approach. The completion of the project may serve as a proof-of-concept for both SNAPP and the team at RUL, for a similar kit of services to be provided in wetland areas.

The data collection will serve to compliment the understanding of RUL's prototype structures, that provide an integrated solution for aeration, pellet feedings, and water pumping, combined with renewable energy from solar panels.

SNAPP will deploy its end-to-end data collection and delivery service, deploying their robotic fish as a non-intrusive mobility solution for data collection. Data deliverables are tailored to fishpond operations, with a particular focus on water quality and water pollution within a stack of general environmental data.

Key Questions

- How do human activities impact water quality in fish ponds?
- How do we innovate monitoring services to further the research of high-tech eco-pond culture?
- How can environmental-DNA methodologies help to identify wetland biodiversity and presence of target species?

Objectives

To create a baseline study on the water quality and conditions of active fish ponds through robotic surveying. Specifically, we aim to:

- Measure key water quality parameters based on the EPD Water Quality Index (Dissolved Oxygen, Biological Oxygen Demand, Ammonia-Nitrates).
- Use automated robotics technology to collect data without disturbing pond culture operations
- Use e-DNA for biodiversity assessment (results and analysis currently still in-progress)
- Combine multi-modal data to assess the state of the ponds

Methodology

Sampling & Surveying

Two ponds adjacent to RUL's prototype structures are selected for the creation of this baseline dataset and report. Site A to the south, and Site B to the north.

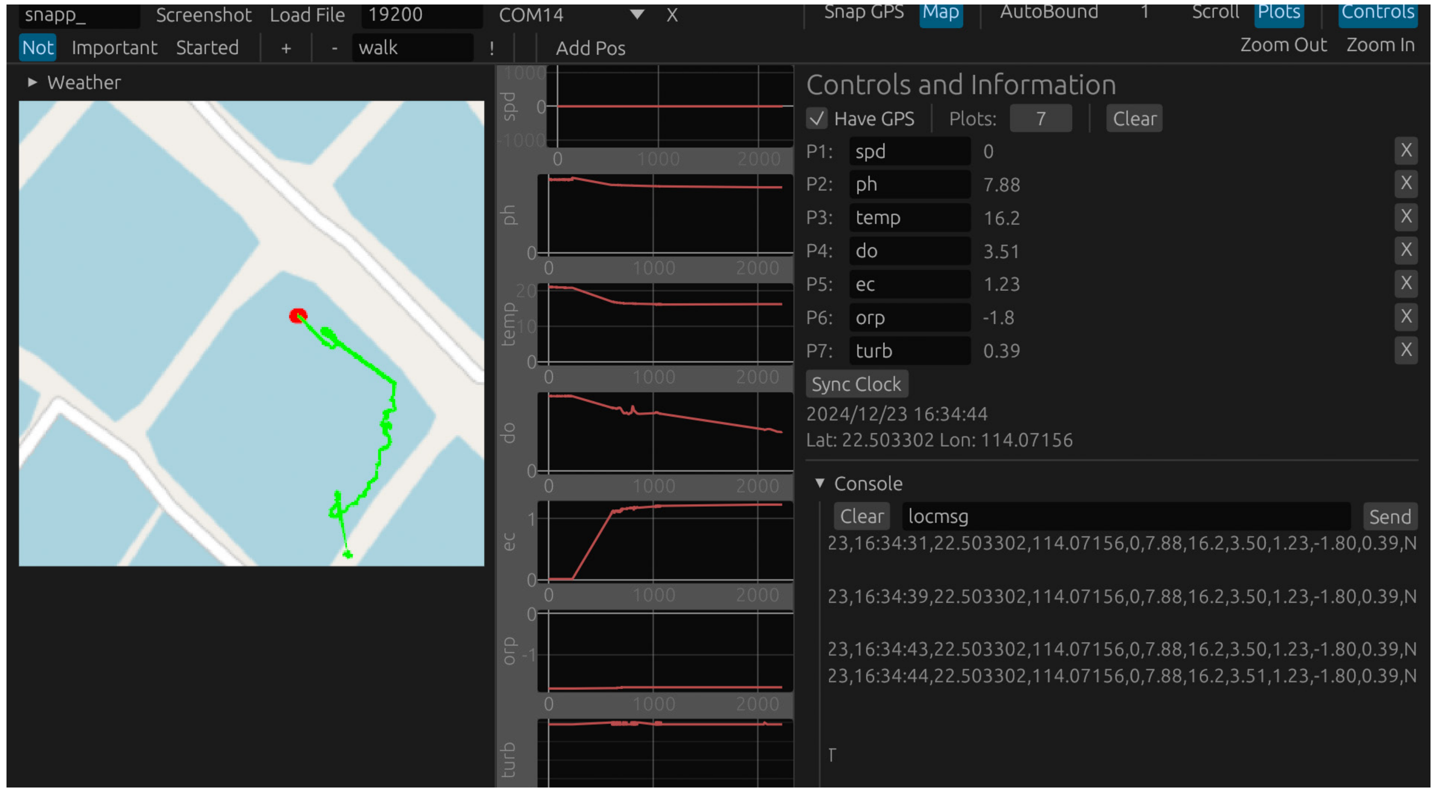
Both ponds are for the production of Flathead Grey Mullet *(Mugil cephalus)*, but differ in their management, in terms of fish feeding and fish catching methods.

Surveys are conducted between the months of September 2024 to December 2024, in the transition between wet and dry seasons. They are occur on a roughly bi-weekly basis, with a priority on similar weather conditions and times of day. Days after storms are avoided where possible, to avoid differences caused by run-off into the pond.

A quadrant sampling method is utilized for data collection of physical parameters. Remotely data collection with Snapp's robotic fish takes sample points are taken every second for 3 minute each for every quadrant, for a total of 15 minutes per pond.

Water samples for chemical and biological analysis is taken at the bund mid-point, between the two ponds. A secchi disc is used for turbidity measurements, and is dropped

Quadrant sampling with robotic fish & data sensor kit



Tablet UI for near-real-time data collection and GPS location

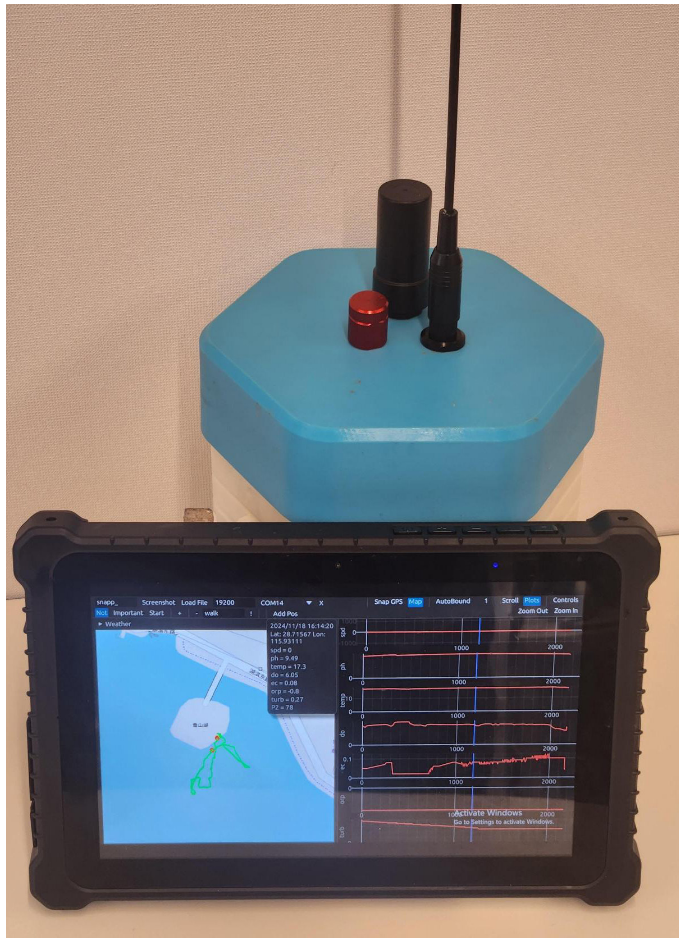
Methodology
Robotic Fish and Sensor Kit

SNAPP's novel robotic fish is deployed for efficient data collection that is non-intrusive to pond operations. It is remote controlled to swim across the pond surface, pulling the sensor kit that is tethered to the back.

The drone is a safe and straightforward method for more comprehensive and diverse sampling, without the hazard of falling into the water if operating a boat. After every deployment, the robotic fish and sensor kit is cleaned with diluted bleach and distilled water to reduce health risk from residual organic pollution, bacteria, and possible parasites.

The fish is remotely operated by a controller with data from the sensor kit transmitted directly to a tablet device where it is stored. With the drone it is possible to generate sample points nearby to live aerators or under suspended cables, that would otherwise be risky by boat.

Robotic fish an sensor kit in pond



Improved sensor kti and tablet UI

Robotic fish with GPS navigation

Methodology

Water Sampling for Chemical and Environmental-DNA (eDNA) Biological Analysis

Water samples are colleted and bottled separtely for third party chemical analysis by SGS and biological eDNA analysis by Prof. Seymour at HKU.

The following protocol is observed for water samples for chemical analysis:

1. Rinse 1L nalgene bottles with sampling water.
2. Submerge jar to collect water, closing the cap under the water to minimize air bubbles that could cause false readings.
3. Transport for lab analysis in dark container, and ideally in an iced cooler.

The following protocol is observed for water samples for biological analysis:

1. Sterilize 1L nalgene bottles for storing sample water with ~10% bleach for an hour, then rinsed an air-dried.
2. Submerge jar to colect water.
3. Transport in dark container, and ideally in an iced cooler.
4. In a sterile environment, filter with soup-bag to remove debris and large particles
5. Lab filtering of water and extraction of DNA


Field blanks


1L nalgene bottles


1L glass bottles


1L prototype remote sampler

Methodology

Table of Physical Parameter Measurements

Parameter	Function	Unit and expected ranges	Reporting limit	Method/techniques used
Dissolved oxygen	Measures the amount of oxygen in water. Oxygen is needed for fish to live	2-6 mg/L	±5% F.S.	Galvanic Dissolved Oxygen Probe
Temperature	Measures the temperature of the lake. The amount of dissolved oxygen increases with temperature.	10-35°C	±0.5°C Temperature Range -10°C to +85°C	Standard Temperature Sensing
pH	Measures the acidity or alkalinity of the water. Fish tend to prefer a neutral to alkaline range.	Dimensionless, 6,5-9	±0.1@25°C	Industrial grade pH probe: 7/24 Industrial Analog pH Meter Kit
Salinity (ERC)	Measures the amount of salt present in water.	0 – 10 ppt	±5%	Once a month
Turbidity	A Secchi disk is lowered until it is no longer visible as a report on turbidity	20 - 60 cm	±5 cm	Secchi Disk
Oxygen-reduction-potential (ORP)	Depends on pollution. Should be close to zero as possible. Measures oxidation potential	-2000mV ~ +2000mV	±8mV/24h	Industrial ORP Indicator Electrode: Platinum Reference Electrode: silver-silver chloride

Results Primer

Five-day biological oxygen demand (BOD5), ammonia-nitrogen, and dissolved oxygen (DO)

What it is

5-Day biological oxygen demand (mg O2/L) is the measure of the concentration of oxygen dissolved in water

Ammonia-nitrogen (mg NH3-N/L) is the measure of the amount of ammonia in a sample as indicator of toxicity fo aquatic life

Dissolved oxygen (mg/L) is the measure of the concentration of oxygen dissolved in water in mg/L

Why it matters

- BOD5 is used to measure natural organic pollution
- Sudden surges in BOD5 levels are indicators of an algae bloom
- Fish will die without enough dissolved oxygen
- Productive fishpond values range from BOD5 10-20 mg/L, with BOD5 50 mg/L as a limit
- BOD5 30 mg/L is the target for the Global Seafood Alliance for shrimp farm effluent
- Uneaten fish feed will contribiute to nitrification
- Low dissolved oxygen levels of DO >2 mg/L can lead to death of fish
- Ammonia content shifts throught the day, as a function of pH and temperature changes
- Ammonia concentrations are expected to be less than 0.5 mg/L in summer, and 2.5 to 4.0 mg/L in winter

References:
1. https://www.globalseafood.org/advocate/water-quality-standards-biochemical-oxygen-demand/#:~:text=In%20aquaculture%20ponds%2C%20BOD5,below%2010%20milligrams%20per%20liter.
2. https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/biochemical-oxygen-demand
3. https://www.ysi.com/File%20Library/Documents/Application%20Notes/A585-Understanding-Ammonia-in-Aquaculture-Ponds.pdf

Results Primer
Water Quality Index (WQI)

What it is

The Water Quality Index (3.0-15.0) is a scoring metric calculated on the total sum score of dissolved oxygen levels, 5-day biological oxygen demand levels, and ammonia-nitrogen levels.

Why it matters

- The WQIs are part of the HK Environmental Protection Department's Water Quality Objectives (WQOs) for monitoring water quality
- They are designed to be indicators of the overall health of rivers.
- While not intended for gauging pond health and productivity, it can be an indicator for organic pollution discharge from ponds into rivers
- Collectively the measures give a condition between "very bad" and "excellent", with Hong Kong rivers being within the "fair" and "excellent" range in recent years

How the Water Quality Index is calculated

No. of points awarded	DO (%saturation)	BOD5 (mg/L)	NH3-N (mg/L)
1	91 – 110	< 3	< 0.5
2	71 – 90 111 – 120	3.1 – 6.0	0.5 – 1.0
3	51 – 70 121 – 130	6.1 – 9.0	1.1 – 2.0
4	31 – 50	9.1 – 15.0	2.1 – 5.0
5	< 30 or > 130	> 15.0	> 5.0

EPD WQI scoring breakdown

How the Water Quality Index is graded

Water Quality Index	Water quality condition
3.0 – 4.5	Excellent
4.6 – 7.5	Good
7.6 – 10.5	Fair
10.6 – 13.5	Bad
13.6 – 15.0	Very Bad

EPD WQI grading

References:
1. https://www.gov.hk/en/residents/environment/water/water/riverwater.htm
2. https://www.epd.gov.hk/epd/misc/river_quality/1986-2005/eng/2_sci_basis_content.htm

Results Primer
Phytoplanktons

What it is

Phytoplanktons are microscopic marine algae. They exist in water and are the food basis for the underwater ecosystem. In a balanced ecosystem, phyoplankton provide food for a wide range of sea creatures including shrim, snails, and jellyfish.

Why it matters

- Phytoplanktons live close to the surface of water as the require sunlight for photosynthesis
- Like plants, phytoplankton consume oxygen. The sudden increase in oxygen demand will cuase the dissolved oxygen levels in water to drop to dangerous levels, potentially suffocating the fish
- Their growth is dependent on inorganic nutrients, with nitrates being the main growth indicator, and phosphorus also playing a role
- Excess nitrates from fish feed, or decaying organic matter can cause an algal bloom
- Algal blooms can produce extremely toxic compounds that have harmful effects on fish, shellfish, mammals, birds, and even people
- A 'good' level of phytoplankton activitiy is necessary for a productive fishpon

References:
1. Moore, C., Mills, M., Arrigo, K. et al. Processes and patterns of oceanic nutrient limitation. Nature Geosci 6, 701–710 (2013). https://doi.org/10.1038/ngeo1765
2. https://oceanservice.noaa.gov/facts/phyto.html

Results Primer
Oxidation-reduction potential (ORP)

What it is

Oxygen-reduction potential (mV) is typically measured to determine the oxidizing or reducing potential of a water sample

Why it matters

- It indicates possible contamination and toxicity, especially when surveying industrial wastewater
- ORP can sometimes be utilized to track the metallic pollution in groundwater or surface water or to determine the chlorine content of wastewater effluent. However, ORP is a nonspecific measurement, i.e., the measured potential is reflective of a combination of the effects of all the dissolved species in the medium
- The value of redox in determining the content of environmental water is greatly enhanced if the user has some knowledge or history of the site
- ORP data can typically become more useful if used as an indicator over time and/or with other common parameters to help develop a complete picture of the water quality being teste
- +100 to +305 mV indicates nitrification
- +50 to +250 mV indicates cBOD degradation with free molecular oxygen
- +25 to +250 mV indicates biological phosphorus removal
- +50 to -50 mV indicates denitrification
- -50 to -250 mV indicates sulfide formation
- -100 to -250 mV indicates biological phosphorus release
- -100 to -225 mV indicates acid formation (fermentation)
- -175 to -400 mV indicates methane production

References:
1. https://www.ysi.com/parameters/orp-redox?srsltid=AfmBOopqXTBMdySooWmOpuB2y2rO6DlIcSzMz9mrIjlplyf3I4UoTo3i
2. https://www.ysi.com/ysi-blog/water-blogged-blog/2013/08/orp-management-in-wastewater-as-an-indicator-of-process-efficiency

Results Primer
Turbidity

What it is

Turbidity (cm) is the measure of water clarity

Why it matters

- Turbidity of a body of water is related to the cleanliness of the water, and is a good indicator of sedimentation, shoreline erosion, excessive algal blooms, and pollution
- Pond culture turbidity levels are expected to be in the range of 20-60 cm, with optimal conditions varying by species
- Highly turbid waters (measures of less than 20 cm) suggest dissolved oxygen depletion and polluted waters, that can reduce productivity
- Minimally turbid waters (measures of more than 60cm) suggest that the water is too clear, and there is inadequate productivity
- Waters with low concentrations of total suspended solids (TSS) are clearer and less turbid than those with high TSS concentrations
- Turbidity can be caused by high concentraions of biota such as phytoplankton, or by loading of abiotic matter such as sediments
- Turbidity is important in aquatic systems as it can alter light intensities through the water column, thus potentiall affecting rates of photosynthesis and the distribution of organisms within the water column. Lowered rates of photosynthesis may in turn affect the levels of dissolved oxygen available, thus affecting larger populations such as fish
- High turbidity can also cause infilling of lakes and ponds if the suspended sediments settle out of the water column and are deposited
- Possible causes of high turbidity are stormwater run-off, shore-line erosion, excessive algal blooms, and pollution

References:
1. https://www.globalseafood.org/advocate/secchi-disk-visibility-correct-measurement-interpretation/

Results Primer
Environmental-DNA (eDNA)

Reporting and analysis is currently in-progress.

What it is

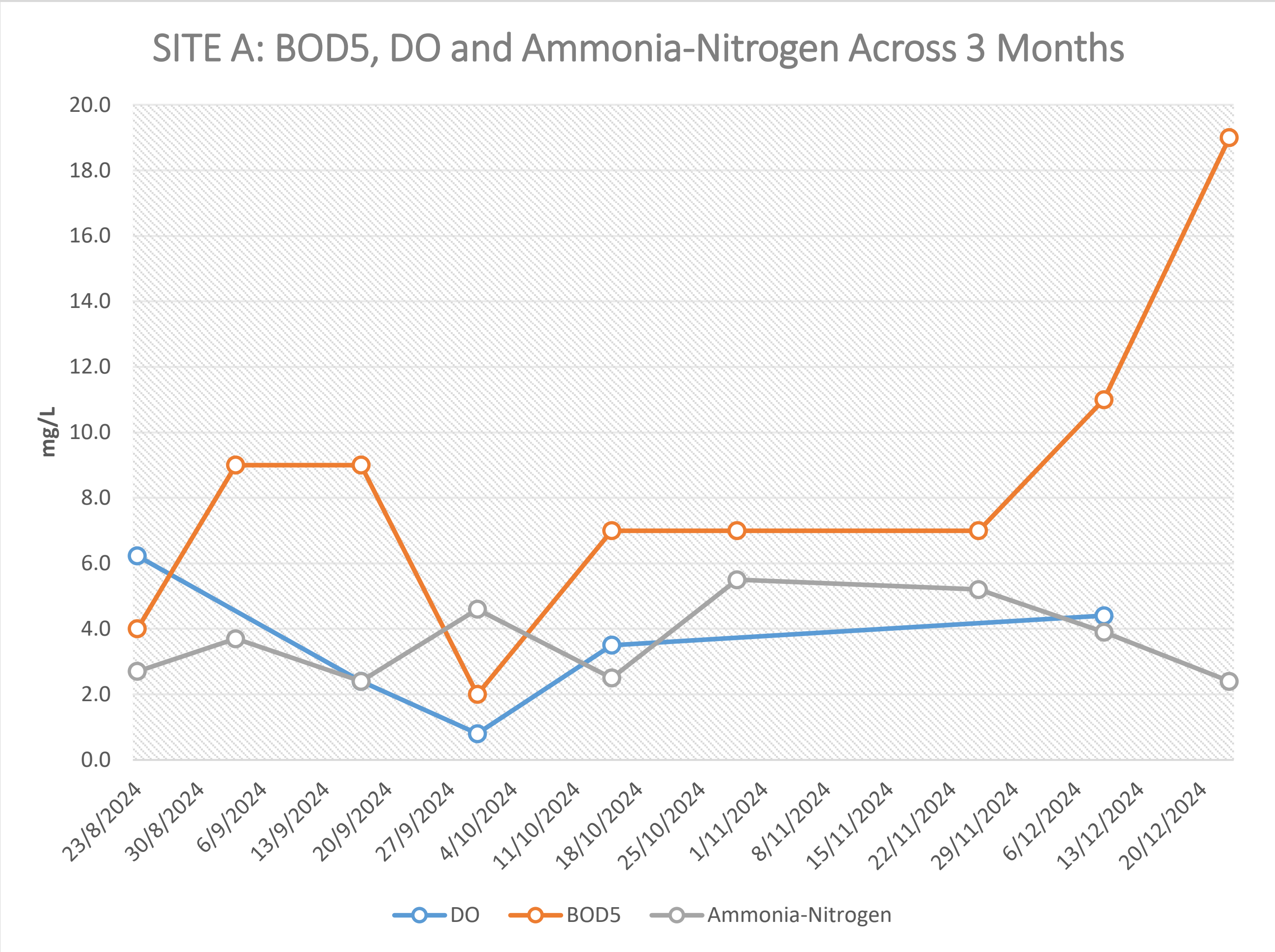
Environmental DNA is the description of genetic material that is observed in environmental samples

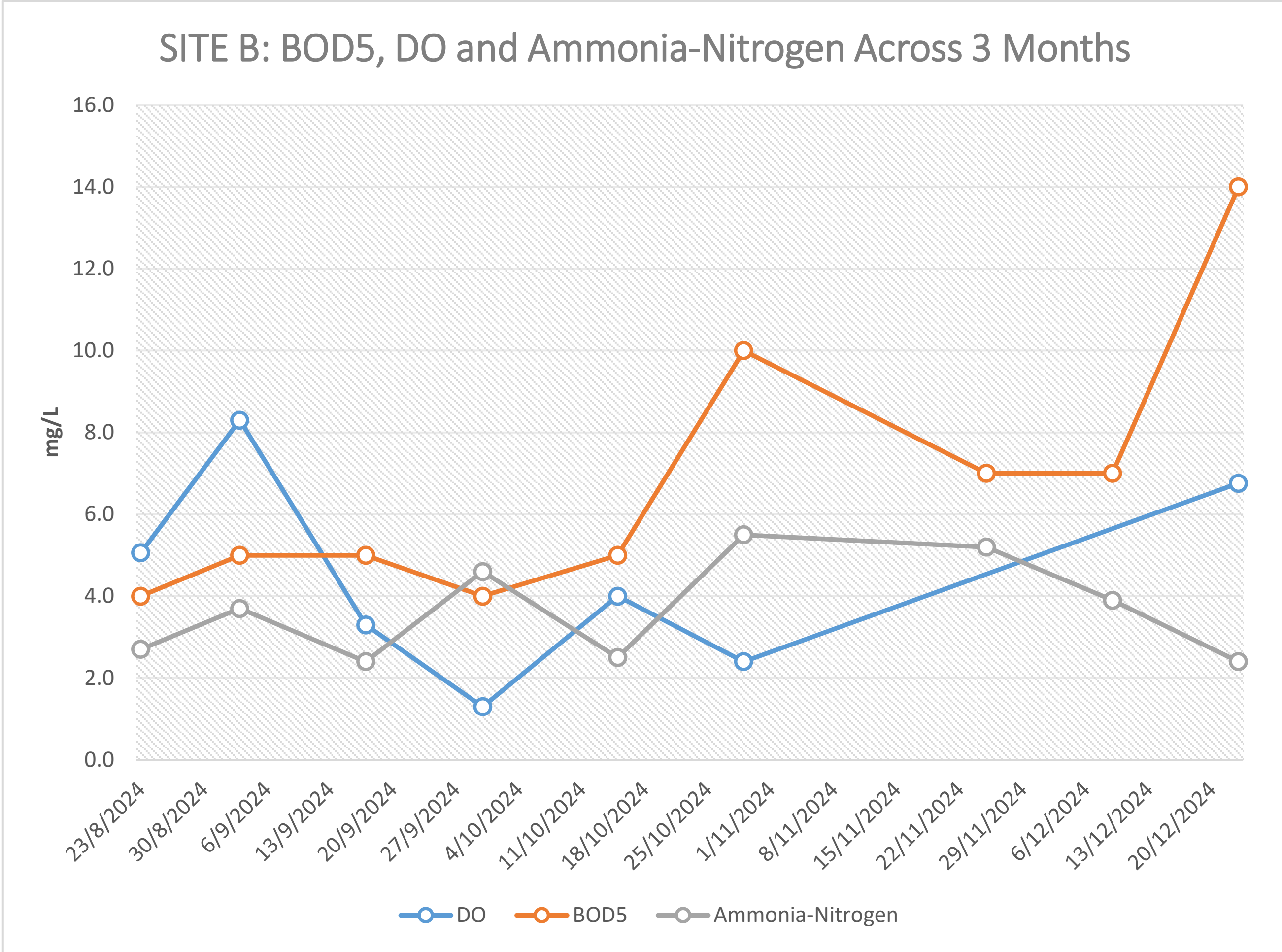
Why it matters

- Biodiversity can be monitored through eDNA genetic sequencing and meta-barcoding
- Biomonitoring through eDNA can compliment point-in-time water chemistry studies with long-term indicators of environmental health, as it is a description of actual presence of living fauna in their habitats
- eDNA is potentially non-intrusive method of obtaining information about biodiversity with minimal disturbance to a site
- Ecological assessment with eDNA can be more rapid and with higher resolution compared to traditional methods
- Both biodiversity classification and quantification can be conducted with eDNA
- Presence of target species can be identified with the appropriate sampling methodology, and can be possible indicators of ecosystem health

References:
1. https://www.globalseafood.org/advocate/secchi-disk-visibility-correct-measurement-interpretation/

Results and Analysis



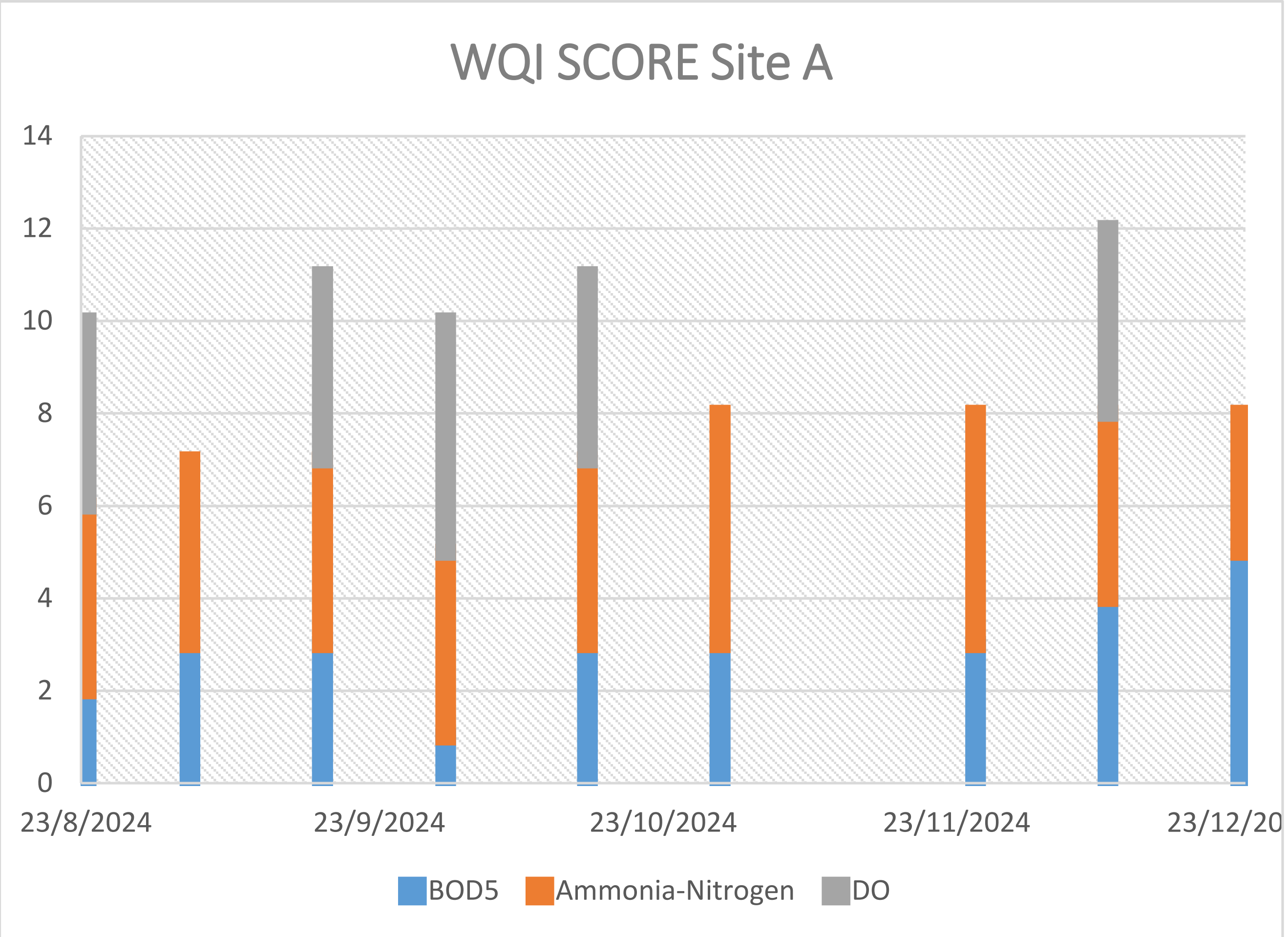


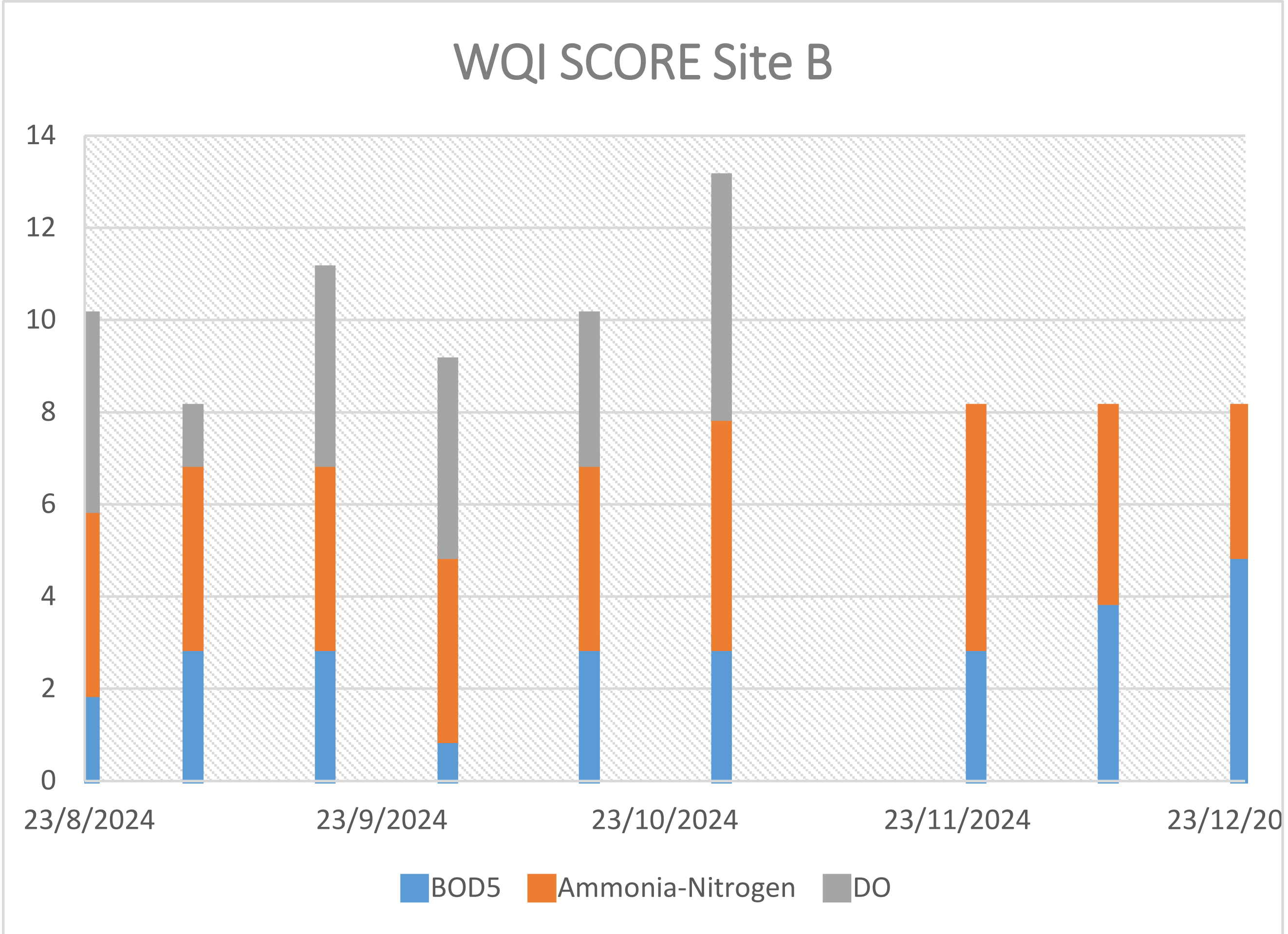
Results and Analysis
Water Nutrient Measures

The analysis reveals notable differences between Site A and Site B, with Site A exhibiting a higher median BOD5 of 7 mg/L vs. 5 mg/L at Site B, correlating with elevated nitrate levels that likely drive phytoplankton growth. This is supported by Site A's consistently lower dissolved oxygen (DO) in Surveys 3–5, particularly the critically low DO of 2.0 mg/L in Survey 4—a threshold risking fish suffocation—which coincided with Site A's peak nitrate values, suggesting intense algal respiration and decomposition overwhelming oxygen supply. However, Survey 4 is also the lowest in terms of BOD5 values, which suggests the least amount of microbes. The occurrence of data is perplexing and requires further investigation.

The inverted turbidity pattern (refer to the turbidity charts) across Surveys 3–5 further aligns with algal dynamics, as blooms increase turbidity initially but may reduce it during die-offs. Alarmingly, December's sudden BOD5 surge paired with nitrate depletion hints at a possible algal crash (organic decay spiking BOD while nitrates are consumed or denitrified), exacerbating hypoxic conditions. These trends underscore Site A's vulnerability to oxygen crises, necessitating urgent interventions to curb nutrient loading and stabilize microbial/algal activity.

While Site A is in an alarming condition, the spikes for both sites in terms of BOD value towards the end of the study requires attention and further data to confirm any long term patterns. There is possibility that the data captured was a sudden spike in BOD at that specific sample point.



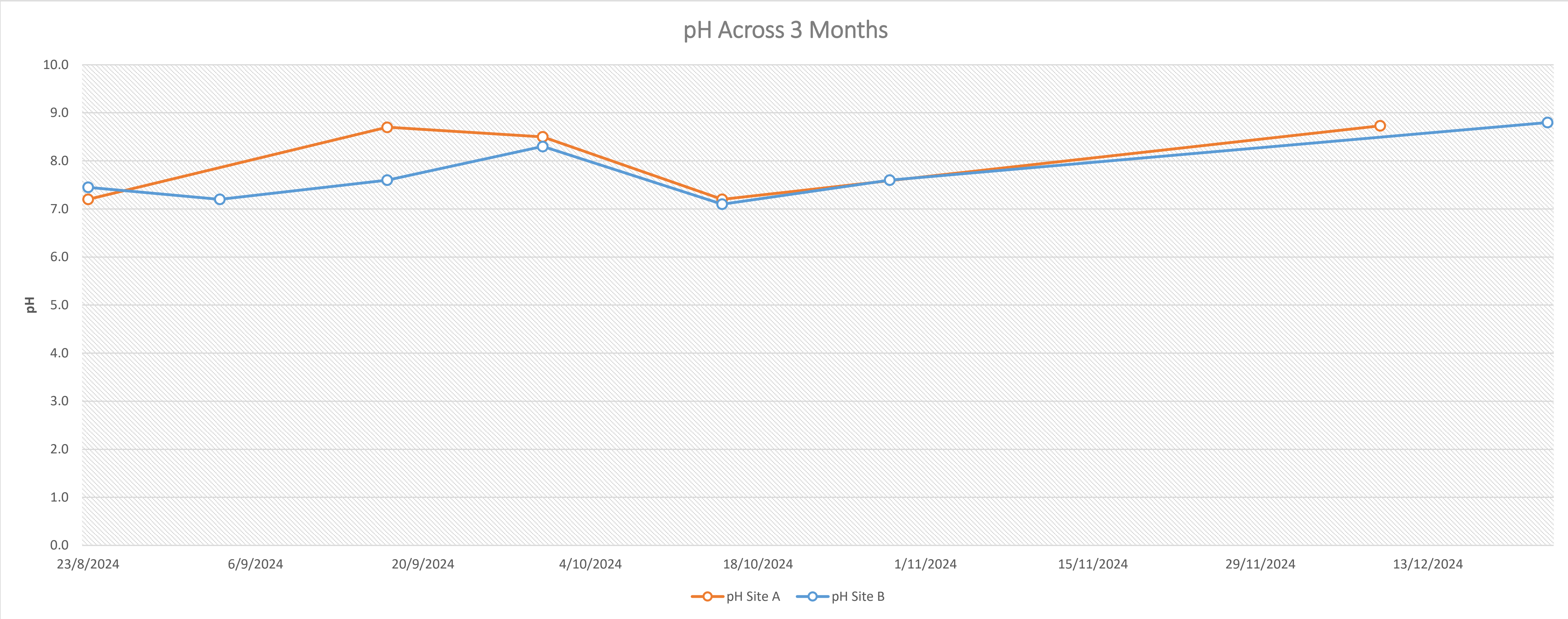


Results and Analysis

Water Quality Index (WQI)

Site B has significantly better scores (3.0-4.5 = excellent, 13.6-15.0 = very bad) compared to Site A in terms of the WQIs. Due to insufficiency in data for (refer to Limitations), further surveys are required for an improved comparitive study.

It is important to note that the WQIs are graded for river waters (refer to Results Primer), and should be observed as partial indicators for polluting effluent discharge, not as indicators for pond culture health or productivity.

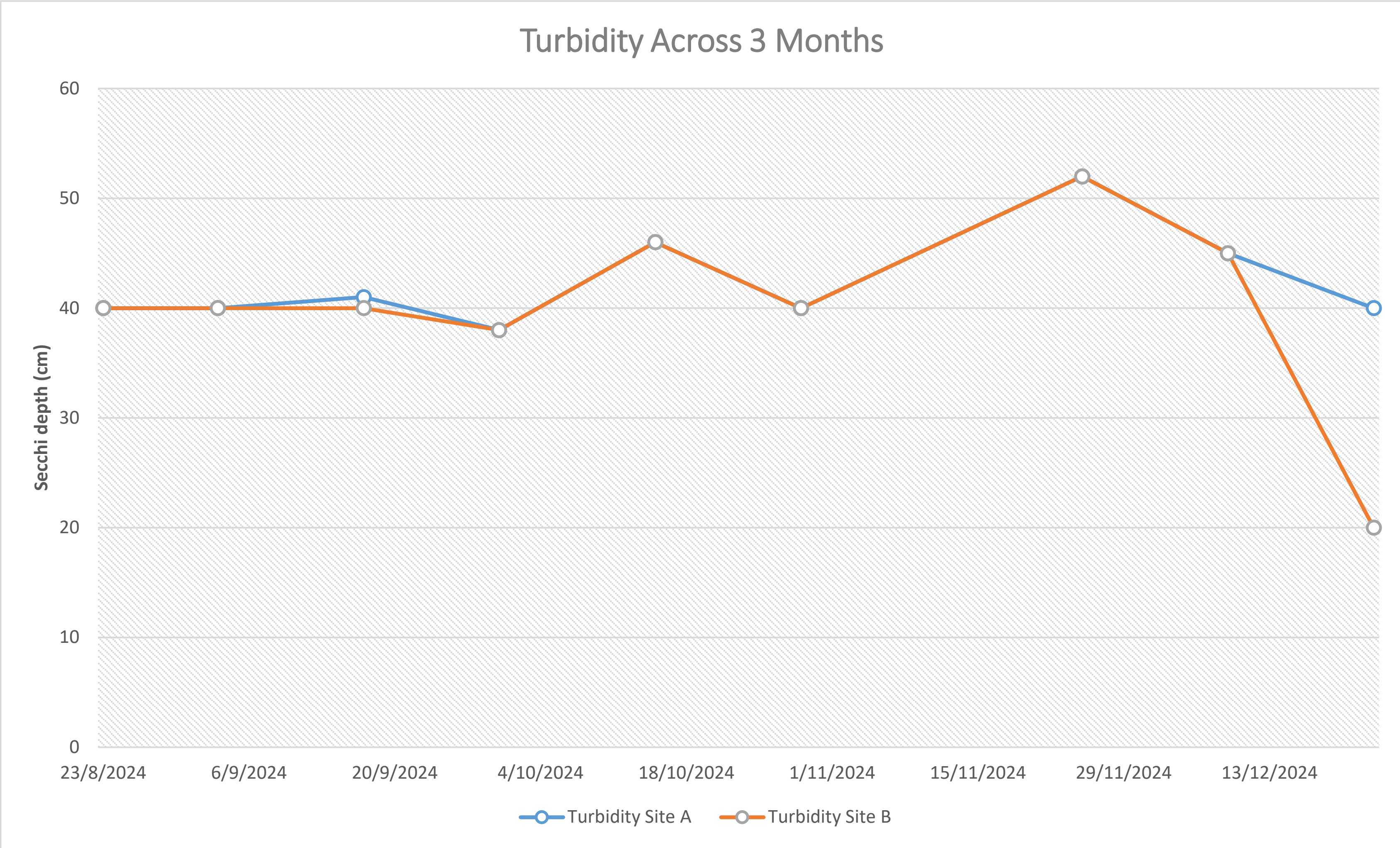


Results and Analysis

Acidity (pH)

Measurements for pH levels fluctuate between pH 7.0 to pH 9.0 for Site A and between pH 7.2 to pH 8.3 for Site B. For both Site A and Site B, the pH values within the desirable pH values for typical pond culture, which is between pH 6.5 and pH 9.0.

To note, the surveys were conducted in the daytime before noon (10:00-11:30 AM*) which with direct sun exposure is the expected produce peak pH levels as a consequence of photosynthetic activity of pond cyanobacteria and algae.



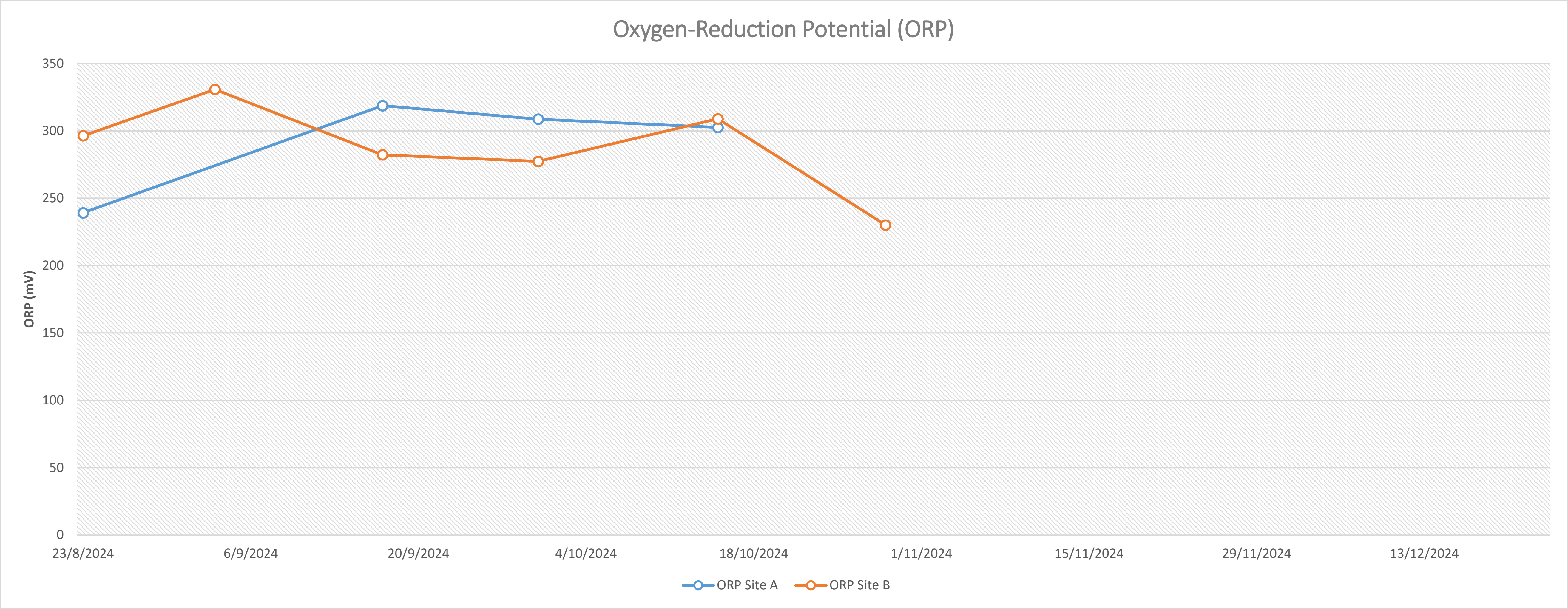
Secchi disc for measuring depth

Results and Analysis
Turbidity

Turbidity measurements were conducted at bi-weekly intervals from August 2024 to December 2024. Throughout the measured timeframe, we observe turbidity values to be relatively stable; with a median value of 40 cm across both sites and a maximum of 52 cm. The 40 cm value is within the productive range for Sechi Disk values. The maximum on the otherhand suggest insufficient phytoplanktons. The value of 40 cm serves as a good baseline for the two fishponds.

There is, however, an observed significant difference for the turbidity values between site A and site B observed on 20th December 2024. Site B had half the turbidity value (smaller is worse) of site A, at only 20 cm. This could indicate strong algae growth. Note that 20 cm is at the dangerous levels for turbidity.

This result, combined with significant increases of BOD5 from baseline (19 mg/L from 7 mg/L) and lower nitrates act as an alarm bell for further action. A second data point should be collected to understand it.



Results and Analysis
Biochemical Reaction (ORP)

The oxidation-reduction potential (ORP) data at the beginning of surveys suggest levels of nitrification, with a gradual decrease over the months.

Nitrification is an expected condition of pond culture due to mirobaterial activity, fish feeding, and excrements. While nitrates are not toxic, nitrification consumes dissolved oxygen and can be a major source of acidity.

It has a healthy positive amount in both sides, further supporting the claim that the pond is in good shape. A high ORP value indicates the presence of strong oxidizing agents like dissolved oxygen (O2). Oxygen is a key driver of oxidative reactions, helping break down pollutants, support fish respiration, and prevent the growth of harmful anaerobic bacteria. Surface water with consistently high ORP values tends to be well-aerated, supporting a healthy, balanced ecosystem.

Summary
Discussion

Critical Baseline

This project established a critical baseline dataset to assess water quality in active fishponds, serving as a foundation for sustainable development of the area into an eco-tourism and research hub.

By integrating a sensing robotic fish the study measured key parameters—dissolved oxygen (DO), oxidation-redox potential (ORP), pH, temperature biological oxygen demand (BOD5), and ammonia-nitrates—to evaluate ecological health.

Of the two sites study, Site A exhibited higher water quality risks due to the possible link to increased productivity. While the median BOD5 remained low at 7 mg/L, the sudden spike in December to 19 mg/L approaches the threshold that could lead to nitrate-driven algal blooms that threaten fish survival.

This baseline data will guide future development work in the area and serve as a reference for future Environmental Impact Assessments. The continuous data collection will tell the story of what is 'good' and productive and what is not, allowing us to balance economic productivity and a protected ecosystem.

Towards Eco-Pond Monitoring

Central to the project was deploying innovative tools: a robotic fish enabled real-time water monitoring without disturbing aquatic life, while e-DNA mapped biodiversity to inform habitat conservation (reporting & analysis currently in-progress). Combined with IoT-driven dashboards, these technologies provided predictive insights into algal blooms and pollution hotspots, creating a model for adaptive management.

By merging ecological data with tech-driven solutions, the project positions the fishpond as a sustainable eco-tourism destination, balancing visitor engagement with biodiversity preservation. Future steps include expanding sensor networks for microplastic detection and AI modeling to simulate tourism impacts, ensuring the site remains a living lab for sustainable aquaculture, education, and climate-resilient design.

Summary **Recommendations**

Increase Feed and Nutrients

Fishponds are in expected conditions for the production of Flathead Grey Mullet (*Mugil cephalus)* that is culvtivated in the ponds throughout the monitoring period.

No significant stressors were detected throughout the entire monitoring period.

The turbidity values of the ponds, with a median reading of 40 cm, are slightly higher than the ideal of 20-30 cm (secchi disc reading), meaning the waters are clearer than what is optimal for *Mugil cephalus* production.

While water turbiditiy is within the typical range of productive ponds (see Results Primer - Turbidity), the findings suggest that suggests that more nutrients, organic matter, and feed can be inputted for increasing productivity.

The decision to increase feed and nutrient inputs should first be validated by experiences and observations of pond operators. Additionally, the growth and spike in BOD5 values should continue to be monitored to understand if it is a natural occuring variance, in response to environmental stressors, or pond productivity. This understanding can inform feed and nutrient inputs, preventing excess.

Increase Aeration

The possible increase of feed and nutrient inputs will need to be balanced with enough aeration to mediate corresponding phytoplankton growth that can be toxic to fish health.

The results suggests that site A has higher phytoplankton growth compared to site B. This could be caused due to the different feeds; as site A used pellets, and side B utilizes bread.

Pellet feed is more easily consumed and degraded in water, and therefore is more likely to leach nutrients into the water through degredation and produce more excrements through consumption. Increased feeding activity will also reduce the dissolved oxygen available in the ponds.

An increase of aeration in correspondence with feeding schedule and weather conditions (affecting phytoplankton growth) could mediate the impact of a more efficient feeding mechansim. This should address the depletion of dissolved oxygen caused by both phytoplankton growth and increased fish activity.

Continued Baseline Study

We recommend conducting a follow-up study on the effect of feed dispersal methods, feed schedule and quantity in relation to fish growth and water quality.

Pond production data should also be collected and processed through an IoT based monitoring system with smart-devices can provide an integrated understanding. The results here could be used as a precursor for feeding programs that is complimentary to wetland conservation goals.

References:
1. https://www.fao.org/fishery/docs/CDrom/aquaculture/I1129m/file/en/en_flatheadgreymullet.htm

Limitations and Future Work

Sampling Difficulties

One of the key goals is to obtain sufficient data to set a baseline and as a first foray toward data-driven insights on pond health. We found manual sampling of the data to be extremely difficult and of limited effectiveness; on the days when we had technical difficulties with the robot, we could only collect data by the edge of the pond. The use of the boat was limited only to Site B, as there was no boat for Site A. To keep results consistent between the two ponds, we only collected the data from the edge of the ponds. We did this by tying our databox and launching it as far as possible from the shoreline to avoid collecting data on murky and stagnant water.

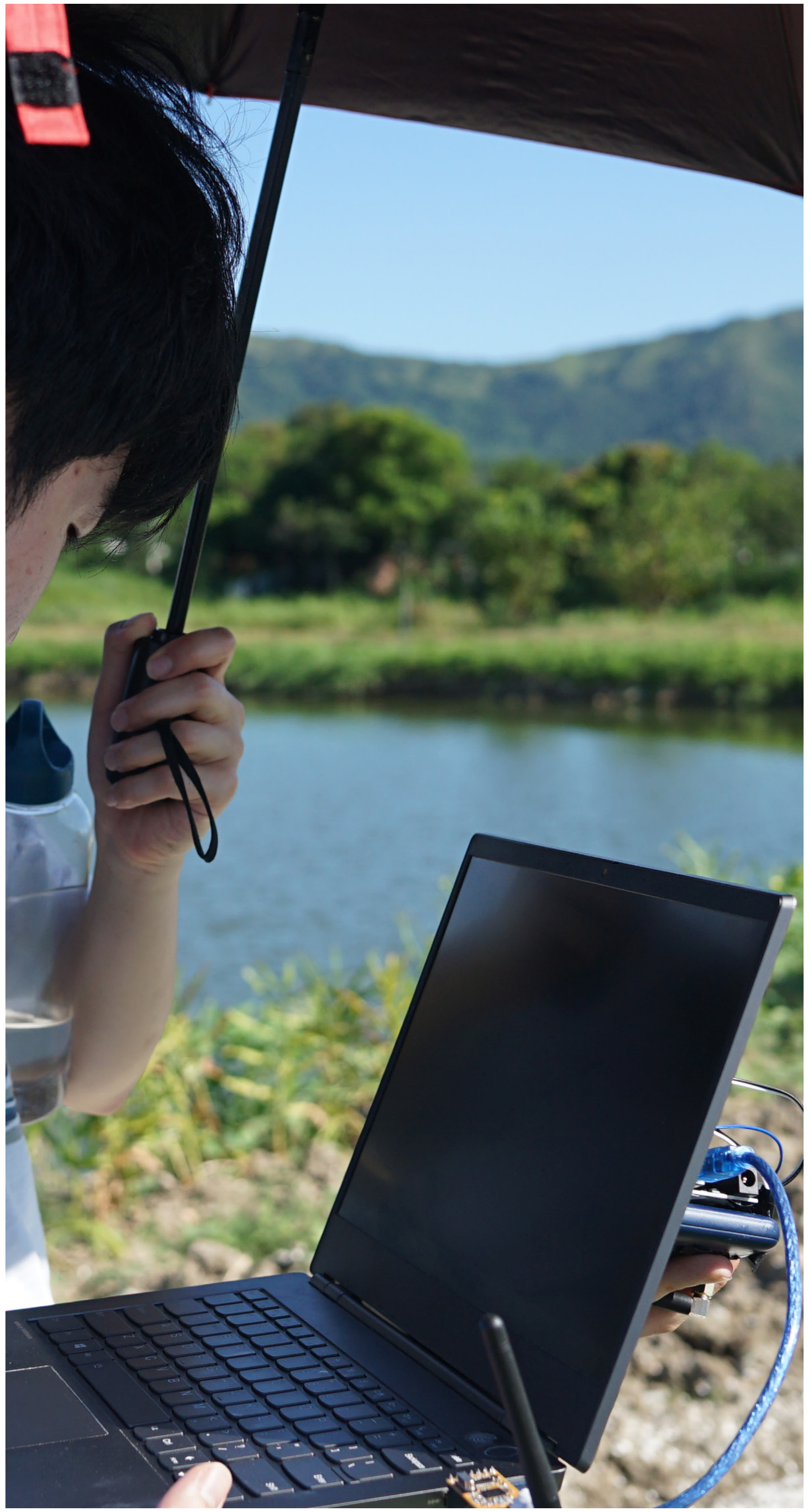
While the prescribed methodology was a quadrant-based sampling, we faced initial challenges in swimming the robot. Some of these hurdles were due to the environment such as entanglement with existing structures (thin wires, aerators), and others were technical challenges related to deployment, waterproofing of sensors and robots, and signal issues. These issues combined account for most of the missing data. The other were related to the processing of data.

Most of these issues has been resolved, with the final dataset collected over 3 quadrants. Regardless of the challenges, we successfully managed to collect a solid set of data that can serve as the baseline for future work. We recommend conducting a follow-up swim to investigate the spatial effect of the distribution of the collected parameters. We hypothesize that there could be possible 'dead zones' as algal bloom distributions are known to be concentrated spatially.

Limitations and Future Work
Data Processing

The next step after sampling was to store the data, process it, and plot the charts to glean useful insights. While the codebase of our robotic system is self-made, the codebase for the data sensors are not as they are third-party sensors. We noticed inconsistencies in the codebase, which led to errant readings, with the code occasionally returning corrupted data. We've since rewrote the sensor code and calibration routines to ensure consistent and accurate reading.

The data cleaning steps posed a challenged as we collect over 300 data points to define the a single sampling point. Our data logs can be as long as 3000 lines per site, with 12 columns of data. The manual processing of all the data is extremely time-consuming, costly and potentially error-prone. We recommend in future works that the entire workflow be integrated and automated by combining the emerging fields of IoT systems and data science to create real-time dashboards accessible from anywhere and at anytime. This will allow the data and information to be disseminated effectively.



Limitations and Future Work

Methodology & Analysis

This baseline study limits the temporal component of the data. While this is sufficient for stable systems, it does not consider the fluctuations of values throughout the day. We've observed on one account (3.30pm data collection as opposed to 11am) that the dissolved oxygen was higher at 6 mg/L. These fluctuations are natural occurrences as oxygen levels rise and fall with the photosynthetic behavior of phytoplanktons. We recommend conducting a temporal study to achieve the following:

- Studying temporal AND spatial changes of dssolved oxygen to identify peaks and lows

- Identifying the affect of other environmental parameters (sunlight, wind) on pond state through statistical methods

- Providing real-time warning systems for potential eutrophication

This baseline data here was collected with a robotic fish with water quality sensors. The dynamic ability allowed us to analyze data spatially. We would like to be opportunistic to suggest conducting the study with *both* temporal and spatial data. The spatial data is sufficient for setting a baseline at the current state of the fishpond as it does not have much human activity. With the goal of upscaling the space for to integrate it with human activities, it would then be important to have both the spatial and temporal baseline to act as comparison for EIA purposes when the fishpond undergoes further development in terms of construction, and also for the future when the fishpond is open to the public as an eco-tourism destination.

Limitations and Future Work **Technology Improvements**

1) Autonomous robotic fish

Biomimetic robotic fish equipped with water-quality probes and autonomous navigation can autonomously collect hourly data (e.g., BOD, nitrates), map pollution hotspots, and return to solar-powered docking stations for recharging and data upload.

2) IoT dashboard & automated reports

A centralized IoT system with edge computing processes sensor data, displays trends on an interactive dashboard, and generates plain-language reports with actionable insights (e.g., nutrient imbalances, maintenance alerts) for stakeholders. This would double as both data for scientist, pond owners, and even for user engagement.

3) Algae sensor with chlorophyll laser technology

Advanced sensors using chlorophyll fluorescence and hyperspectral imaging can detect algal species in real-time, predict harmful blooms, and trigger automated mitigation systems (e.g., UV lights or aeration) to prevent oxygen crashes and toxin release. We then combine this with drone footage for a full GIS system.

4) Microplastic sensing for fish farms

A centralized IoT system with edge computing processes sensor data, displays trends on an interactive dashboard, and generates plain-language reports with actionable insights (e.g., nutrient imbalances, maintenance alerts) for stakeholders. This would double as both data for scientist, pond owners, and even for user engagement.

5) Smart rebalancing pumps

AI-controlled pumps can redistribute water between ponds or through biochar filters to dilute pollutants (e.g., nitrates), stabilize ecosystems, and integrate with aquaponics for nutrient recycling, all powered by renewable energy.

Appendix

Site A (South Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	31.9	Normal
	Dissolved Oxygen (mg/L)	6.2	Normal
	pH	7.2	Normal
	ERC (us/cm)	86.3	-
	ORP (mV)	239.2	Normal
Manual Dataset	Turbidity (cm)	40	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	4	Low
	Ammonia-Nitrogen (mg NH3-N/L)	2.7	Normal

Site B (Nouth Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	30.4	Normal
	Dissolved Oxygen (mg/L)	5.1	Normal
	pH	7.5	Normal
	ERC (us/cm)	50.1	-
	ORP (mV)	296.4	Normal
Manual Dataset	Turbidity (cm)	40	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	4	Low
	Ammonia-Nitrogen (mg NH3-N/L	1.8	Normal

Survey 1

Survey date:	August 23, 2024
Survey time:	10:00-11:00 AM
Air Temperature:	25 C
Wind speed:	20 km/h
Rainfall:	0 mm
Cloud coverage:	-

Conditions are normal for with low BOD5, possibly due to early stages of pond production cycle. Bread is scattered on the bund corners for both ponds, and one aerator is switched on for each pond.

Aerial imagery, (Left) Site B, (Right) Site A

*The rating is based on generalized conditions of fishponds as stated in the "Results Primer" and so is for general reference purposes only.

Site A (South Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	-	-
	Dissolved Oxygen (mg/L)	-	-
	pH	-	-
	ERC (us/cm)	-	-
	ORP (mV)	-	-
Manual Dataset	Turbidity (cm)	40	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	9	Low
	Ammonia-Nitrogen (mg NH3-N/L)	3.7	Normal

Site B (Nouth Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	33.4	Normal
	Dissolved Oxygen (mg/L)	8.3	High
	pH	7.2	Normal
	ERC (us/cm)	960.6	-
	ORP (mV)	330.8	High
Manual Dataset	Turbidity (cm)	40	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	5	Low
	Ammonia-Nitrogen (mg NH3-N/L	2.3	Normal

Survey 2

Survey date:	September 03, 2024
Survey time:	10:00-11:00 AM
Air Temperature:	32 C
Wind speed:	9 km/h
Rainfall:	0 mm
Cloud coverage:	23 %

Missing data for Site A due to unforseen challenges on-site. Conditions for Site B are mostly normal with high DO and low BOD5. ORP is higher than expected ranges.

Aerial imagery not available for this survey

*The rating is based on generalized conditions of fishponds as stated in the "Results Primer" and so is for general reference purposes only.

Site A (South Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	32.6	Normal
	Dissolved Oxygen (mg/L)	2.4	Normal
	pH	8.7	High
	ERC (us/cm)	25.6	-
	ORP (mV)	318.7	High
Manual Dataset	Turbidity (cm)	41	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	9	Low
	Ammonia-Nitrogen (mg NH3-N/L)	2.4	Normal

Site B (Nouth Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	32.2	Normal
	Dissolved Oxygen (mg/L)	3.3	Normal
	pH	7.6	Normal
	ERC (us/cm)	31.1	-
	ORP (mV)	282.2	Normal
Manual Dataset	Turbidity (cm)	40	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	5	Low
	Ammonia-Nitrogen (mg NH3-N/L	1.6	Normal

Survey 3

Survey date:	Septebmer 17, 2024
Survey time:	10:00-11:00 AM
Air Temperature:	-
Wind speed:	-
Rainfall:	-
Cloud coverage:	-

Site A features high pH and and DO that is on the lower end of the expected range. Site B conditions are mostly normal. Both sites have low BOD5. Bread is scattered on the bund corners for both ponds, and one aerator is switched on for each pond.

Aerial imagery, (Left) Site B, (Right) Site A

*The rating is based on generalized conditions of fishponds as stated in the "Results Primer" and so is for general reference purposes only.

Site A (South Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	31.8	Normal
	Dissolved Oxygen (mg/L)	0.8	Low
	pH	8.5	High
	ERC (us/cm)	49.1	-
	ORP (mV)	308.6	High
Manual Dataset	Turbidity (cm)	38	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	2	Low
	Ammonia-Nitrogen (mg NH3-N/L)	4.6	High

Site B (Nouth Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	32	Normal
	Dissolved Oxygen (mg/L)	1.8	Low
	pH	8.3	High
	ERC (us/cm)	67.9	-
	ORP (mV)	277.3	Normal
Manual Dataset	Turbidity (cm)	38	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	4	Low
	Ammonia-Nitrogen (mg NH3-N/L	2.5	Normal

Survey 4

Survey date: September 30, 2024

Survey time: 10:00-11:00 AM

Air Temperature: 34 C

Wind speed: 6 km/h

Rainfall: 0 mm

Cloud coverage: 12 %

Both sides have dangerously low DO levels, which has the possibility of equipment error. The pH levels are more elevated than normal. The BOD5 levels for both ponds are still much lower than expected for a productive pond. One aerator is switched on for each pond.

Aerial imagery, (Left) Site B, (Right) Site A

*The rating is based on generalized conditions of fishponds as stated in the "Results Primer" and so is for general reference purposes only.

Site A (South Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	29.3	Normal
	Dissolved Oxygen (mg/L)	3.5	Normal
	pH	7.2	Normal
	ERC (us/cm)	792	-
	ORP (mV)	302.5	Normal
Manual Dataset	Turbidity (cm)	46	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	7	Low
	Ammonia-Nitrogen (mg NH3-N/L)	2.5	Normal

Site B (Nouth Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	28.7	Normal
	Dissolved Oxygen (mg/L)	4	Normal
	pH	7.1	Normal
	ERC (us/cm)	974.5	-
	ORP (mV)	308.9	High
Manual Dataset	Turbidity (cm)	46	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	5	Low
	Ammonia-Nitrogen (mg NH3-N/L	2.7	Normal

Survey 5

Survey date: October 15, 2024
Survey time: 10:00-11:00 AM
Air Temperature: 31 C
Wind speed: 10 km/h
Rainfall: 1.25 mm
Cloud coverage: 0 % (actual site condition is cloudy despite weather data)

Both sites have normal conditions, with BOD5 still at low levels. Site B shows a higher than expected ORP value. No aerators are swithced on.

Aerial imagery, (Left) Site B, (Right) Site A

*The rating is based on generalized conditions of fishponds as stated in the "Results Primer" and so is for general reference purposes only.

Site A (South Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	-	-
	Dissolved Oxygen (mg/L)	-	-
	pH	-	-
	ERC (us/cm)	-	-
	ORP (mV)	-	-
Manual Dataset	Turbidity (cm)	40	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	7	Low
	Ammonia-Nitrogen (mg NH3-N/L)	5.5	High

Site B (Nouth Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	24.2	Normal
	Dissolved Oxygen (mg/L)	2.4	Normal
	pH	7.6	Normal
	ERC (us/cm)	919.7	-
	ORP (mV)	230	Normal
Manual Dataset	Turbidity (cm)	40	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	10	Normal
	Ammonia-Nitrogen (mg NH3-N/L	2.7	Normal

Survey 6

Survey date: October 29, 2024
Survey time: 10:00-11:00 AM
Air Temperature: 27 C
Wind speed: 15 km/h
Rainfall: 0 mm
Cloud coverage: 0 %

Missing data for Site A due to unforseen challenges on-site. Conditions for Site B are normal for all datasets, with Site A showing high ammonia-nitrogen content that can lead to water toxicity. No aerators are switched on for each pond.

Aerial imagery, (Left) Site B, (Right) Site A

*The rating is based on generalized conditions of fishponds as stated in the "Results Primer" and so is for general reference purposes only.

Site A (South Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	-	-
	Dissolved Oxygen (mg/L)	-	-
	pH	-	-
	ERC (us/cm)	-	-
	ORP (mV)	-	-
Manual Dataset	Turbidity (cm)	52	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	7	Low
	Ammonia-Nitrogen (mg NH3-N/L)	5.2	High

Site B (Nouth Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	-	Normal
	Dissolved Oxygen (mg/L)	-	Normal
	pH	-	Normal
	ERC (us/cm)	-	-
	ORP (mV)	-	Normal
Manual Dataset	Turbidity (cm)	52	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	3	Normal
	Ammonia-Nitrogen (mg NH3-N/L	2.7	Normal

Survey 7

Survey date: November 25, 2024

Survey time: 10:00-11:00 AM

Air Temperature: 21 C

Wind speed: 15 km/h

Rainfall: 0 mm

Cloud coverage: 26 %

Missing data for both sites due to corruption of data. Site A showing high ammonia-nitrogen content that can lead to water toxicity. Site B has bread scattered along the pond edge. No aerators are switched on for each pond.

Aerial imagery, (Left) Site B, (Right) Site A

*The rating is based on generalized conditions of fishponds as stated in the "Results Primer" and so is for general reference purposes only.

Site A (South Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	21.2	Normal
	Dissolved Oxygen (mg/L)	4.4	Normal
	pH	8.73	High
	ERC (us/cm)	-	-
	ORP (mV)	-	-
Manual Dataset	Turbidity (cm)	0.45	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	11	Normal
	Ammonia-Nitrogen (mg NH3-N/L)	3.9	Normal

Site B (Nouth Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	-	Normal
	Dissolved Oxygen (mg/L)	-	Normal
	pH	-	Normal
	ERC (us/cm)	-	-
	ORP (mV)	-	-
Manual Dataset	Turbidity (cm)	0.45	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	7	Normal
	Ammonia-Nitrogen (mg NH3-N/L	1.6	Normal

Survey 8

Survey date: December 09, 2024
Survey time: 10:00-11:00 AM
Air Temperature: 16 C
Wind speed: -
Rainfall: 0 mm
Cloud coverage: 0 % (actual conditions are sparsely cloudy)

Missing data for Site B due to unforseen challenges on-site. ERC and ORP values are no longer collected. Site A has higher pH than normal, and BOD5 levels have reached expected levels. Site B has bread scattered along the pond edge. No aerators are switched on for each pond.

Aerial imagery, (Left) Site B, (Right) Site A

*The rating is based on generalized conditions of fishponds as stated in the "Results Primer" and so is for general reference purposes only.

Site A (South Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	-	-
	Dissolved Oxygen (mg/L)	-	-
	pH	-	-
	ERC (us/cm)	-	-
	ORP (mV)	-	-
Manual Dataset	Turbidity (cm)	40	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	19	Normal
	Ammonia-Nitrogen (mg NH3-N/L)	2.4	Normal

Site B (Nouth Pond)			
Category	**Dataset**	**Values**	**Rating***
Water Sensor Dataset	Temperature (C)	21.1	Normal
	Dissolved Oxygen (mg/L)	6.8	High
	pH	8.8	High
	ERC (us/cm)	-	-
	ORP (mV)	-	-
Manual Dataset	Turbidity (cm)	20	Normal
Water Chemistry Dataset	Biological Oxygen Demand BOD5 (mg O2/L)	14	Normal
	Ammonia-Nitrogen (mg NH3-N/L	1	Normal

Survey 9

Survey date: December 23, 2024

Survey time: 10:00-11:00 AM

Air Temperature: 14 C

Wind speed: 17 km/h

Rainfall: 0 mm

Cloud coverage: 100 %

Missing data for Site A due to unforseen challenges on-site. Site A shows normal conditions with BOD5 levels spiking at higher end of normal range. Site B has higher pH and DO than normal, with BOD5 within the normal range.

Aerial imagery not available for this survey

*The rating is based on generalized conditions of fishponds as stated in the "Results Primer" and so is for general reference purposes only.

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