“Sustainable Aquaculture Practices: Implementing Integrated Multi-Trophic Aquaculture (IMTA) Systems in Open Water, Hatcheries, and Ponds - A Case Study from Cox's Bazar, Bangladesh”

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Certificate,

This is to certify that this internship project report entitled **"Sustainable Aquaculture Practices: Implementing Integrated Multi-Trophic Aquaculture (IMTA) Systems in Open Water, Hatcheries, and Ponds - A Case Study from Cox's Bazar, Bangladesh"** i submitted by MD. Nazmus Sakib has been carried out under my supervision. This is to further certify that it is an original work and suitable for partial fulfillment of the degree of Master's in Oceanography, Shahjalal University of Science and Technology. I found him sincere and honest in his work. I knowingly certify that this report is an original one and has not been submitted elsewhere previously for publication in any form.

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Supervisor

Dr. Md Asaduzzaman

Associate Professor
Department of Marine Bioresource Scienc
Faculty of Fisheries

Candidates Declaration

I, hereby, declare that this internship paper entitled **“Sustainable Aquaculture Practices: Implementing Integrated Multi-Trophic Aquaculture (IMTA) Systems in Open Water, Hatcheries, and Ponds - A Case Study from Cox's Bazar, Bangladesh”** is a presentation of my original work. I also affirm that I have not submitted any portion of this work elsewhere for a degree award.

Md Nazmus Sakib

Reg. No: 2022126008
Master's 2nd semester
Session: 2022-2023
Department of Oceanography,
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I want to express my deep and sincere gratitude to my supervisor, Dr Ashaduzzaman, Associate Professor and Head, Department of Marine Bioresource Science, Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University, for allowing me to do an internship and providing invaluable guidance throughout this internship to complete my internship project. His dynamism, vision, sincerity, and motivation have deeply inspired me. It was a great privilege and honour to work and study under his guidance. I am extremely grateful for what he has offered me. In preparation, I would also like to thank him for his friendship, empathy, and great sense of humour.

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MD Nazmus Sakib

Executive Summery

The study mainly focused on the differences in the parameters (Temperature, Salinity, and pH) among three different IMTA (Integrated Multi-Trophic Aquaculture) environments: open-water, pond, and hatchery. Our study was conducted in three different areas: the open aquaculture site was located in Khurushkul-Moheshkhali, the pond was situated in Khurushkul Dakkhin Para, and the hatchery was located in Dorianagar under CVASU. This study was mainly based on three different species in one aquaculture system. IMTA brings together species from different trophic levels—in this case, *Gracilaria* spp. (seaweed), *Perna viridis* (green mussel), and *Mystus gulio* (Nona Tengra fish).The data was collected on a weekly basis over a one-month period from the three different culture systems.

We saw the highest temperature in the Hatchery at 24.15°C, while the lowest temperature was recorded in the Open Ocean IMTA at 22.82°C. The highest salinity was found in the Open Ocean IMTA at 30.50 ppt, whereas the lowest salinity occurred in the Pond system at 6.59 ppt. For pH, the highest average was again observed in the Open Ocean IMTA at 7.29, and the lowest in the Pond system at 7.10.This study is essential not only for advancing sustainable aquaculture practices but also for enhancing the socioeconomic well-being of coastal communities.

Keywords: Integrated Multi-Trophic Aquaculture (IMTA), sustainable aquaculture, Gracilaria spp., Perna viridis, Mystus gulio, water quality, Cox’s Bazar.

1.INTRODUCTION:

Aquaculture is an important sector for Bangladesh's economy and food security, supported by its 45,000 km² inland water resources and 710 km coastline (Ghose, 2014).Millions of Bangladesh's coastal people rely on this aquaculture industry for their source of income, but it also provides over 60% of the animal protein consumed, so it is absolutely essential for adequate nutrition (Ghose, 2014). Yet in addition to frequent disasters such as cyclones and floods, the aquaculture sectors of Bangladesh is under increasing strain from pollution, climate change, and environmental damage. Further aggravated these issues are unsustainable methods of fishing in the coastal area and overfishing, therefore compromising long-term food security and the biological equilibrium of aquatic habitats (Ghose, 2014; Ahmed & Glaser, 2016).

In order to solve this problem Integrated Multi-Trophic Aquaculture (IMTA) is a revolutionary aquaculture methods for sustainable aquaculture. IMTA aquaculture is a method where we can culture different species across various trophic levels, including finfish, shellfish, and seaweeds. In aquaculture systems, other species gather the food that one species consumes on the ocean floor. To solve this issue, IMTA can circulate this energy, and every cultured species can take it, hence generating a circular economy whereby waste from one species becomes a resource for another (Troell et al., 2009; Li, 1987).

Chinese adopted the IMTA aquaculture techniques in the early 1980s because of their ability to i ncrease production by 67-92% while also reducing environmental damage, therefore creating a model for global acceptance (Li, 1987; Troell et al., 2009).Most of the time in monoculture, environmental issues such as nutrient accumulation, eutrophication, and habitat degradation arise, therefore compromising the area's biodiversity (Ryther et al., 1972; Buschmann et al., 2001). We can get better via the IMTA.

Ecological reciprocity is another term of IMTA becasue of it,s unique and successful method. Tiny fish produce organic waste and excess feed, which extractive species like filter-feeding oysters (*Crassostrea gigas*) and nutrient-absorbing seaweeds (*Gracilaria spp)*use in IMTA aquaculture.The IMTA method improves farming and water quality by removing excess nutrients from the water (Abreu et al., 2011; Buschmann et al., 2001). In this particular culture area, benthic organisms like sea cucumbers (*Stichopus japonicus*) improve the sediment quality and recycle organic materials from the sediments (Troell et al., 2009). IMTA culture also has some benefits. For example, in Bangladesh, IMTA systems that mixed carps (*Catla catla*), stinging catfish (*Heteropneustes fossilis*), and aquatic plants (*Ipomoea aquatica*) increased biomass yields by 35% compared to monoculture (Kibria & Haque, 2018).

Cox's Bazar is known as the most suitable place for the IMTA because of the dynamic ecosystem and low labor cost. Open water IMTA can be seen in most of Cox's Bazar. This is where seaweeds (*Glacilaria spp.*) and mussels (*Mytilus edulis*) are grown, which helps remove excess nutrients from the water and increases biodiversity (Irisarri et al., 2015; Biswas et al., 2019). For instance, Biswas et al. (2019) proposed the brackish water IMTA, incorporating multiple species simultaneously, which not only enhanced productivity but also improved environmental remediation. But there are some problems also; the Cox's Bazar area vulnerability to cyclones, salinity changes, and seasonal species variability presents major difficulties for this culture (Ahmed & Glaser, 2016; Hossain et al., 2022).

According to Kibria and Haque (2018), although the IMTA is the best aquaculture, there are problems that the policymakers faced, including policy development, proper management, reliance on expensive imported feed, and the integration between the different species. Furthermore, infrastructure-related problems and proper resource management problems are also shown during this culture, for example, the seaweed infrastructure (Tullberg et al., 2022; Ahmed & Glaser, 2016). According to Hossain et al. (2022), we can overcome these challenges with extension services, capacity-building initiatives, and collaboration with stakeholders. To increase the IMTA for the coastal communities, the government has to take some initiatives and also improve the participatory governance models and also feasibility for the coastal communities (Reid et al., 2018; Chopin et al., 2010).

1.1 SIGNIFICANCE

This study holds significant value in understanding the ecological and socio-economic impacts of Integrated Multi-Trophic Aquaculture (IMTA) in the coastal region of Cox's Bazar, Bangladesh. By evaluating three distinct IMTA systems—open-water (Moheshkhali), pond (Khurushkul Dakkhin Para), and hatchery-based (Dorianagar under CVASU)—the project provides comprehensive insights into how different environmental settings influence aquaculture sustainability.

Weekly monitoring of key water quality parameters such as temperature, salinity, and pH enabled a scientific assessment of the physiochemical conditions maintained across these systems. This contributes to improved management practices and environmental monitoring in IMTA operations.

Importantly, the study also highlights the socio-economic relevance of IMTA, demonstrating its potential to support coastal livelihoods through environmentally friendly and cost-effective aquaculture practices. It underscores how IMTA can promote a balanced ecosystem, reduce input costs, and offer sustainable income opportunities for coastal communities.

Despite challenges such as infrastructure limitations, lack of awareness, and dynamic environmental conditions in open-water systems, the study lays a foundation for future development. It suggests the need for adaptive strategies including policy support, community engagement, and education on IMTA practices.

Overall, this case study supports the broader goal of sustainable aquaculture by showcasing the ecological and economic benefits of IMTA systems, aligning with national and global efforts for blue growth and coastal resilience.

1.2 OBJECTIVES:

1.To understand the different Culture Techniques for IMTA Systems Across Pond, River, and Hatchery Environments.
2. Determine the Physical Parameters (Temperature, Salinity and PH) in IMTA in Pond, River, and Hatchery Systems.

1.3 Project overview

The internship we perticipated was part of the larger initiative titled "Development of IMTA Technology to Revitalize and Sustain the Life Expectancy of Coastal Communities of the Southeast Coast of Bangladesh." The project is being implemented by the Department of Marine Bioresource Science at Chattogram Veterinary and Animal Sciences University (CVASU), with economical support from WorldFish under the Asia-Africa BlueTech Superhighway (AABS) Project.

Led by Dr. Ashaduzzaman, Associate Professor in the Department of Fisheries at CVASU, this initiative focuses on developing and testing Integrated Multi-Trophic Aquaculture (IMTA) systems in three distinct environments: ponds, hatcheries, and open-water sites. The goal is to create a sustainable aquaculture model that not only protects the environment but also strengthens the economic resilience of coastal communities.

By combining species from different trophic levels—such as seaweed, mussels, and finfish—IMTA offers a nature-based solution that promotes resource efficiency, reduces waste, and supports local livelihoods. This project reflects a broader vision of building climate-resilient, eco-friendly aquaculture systems that can be scaled across vulnerable coastal regions of Bangladesh.

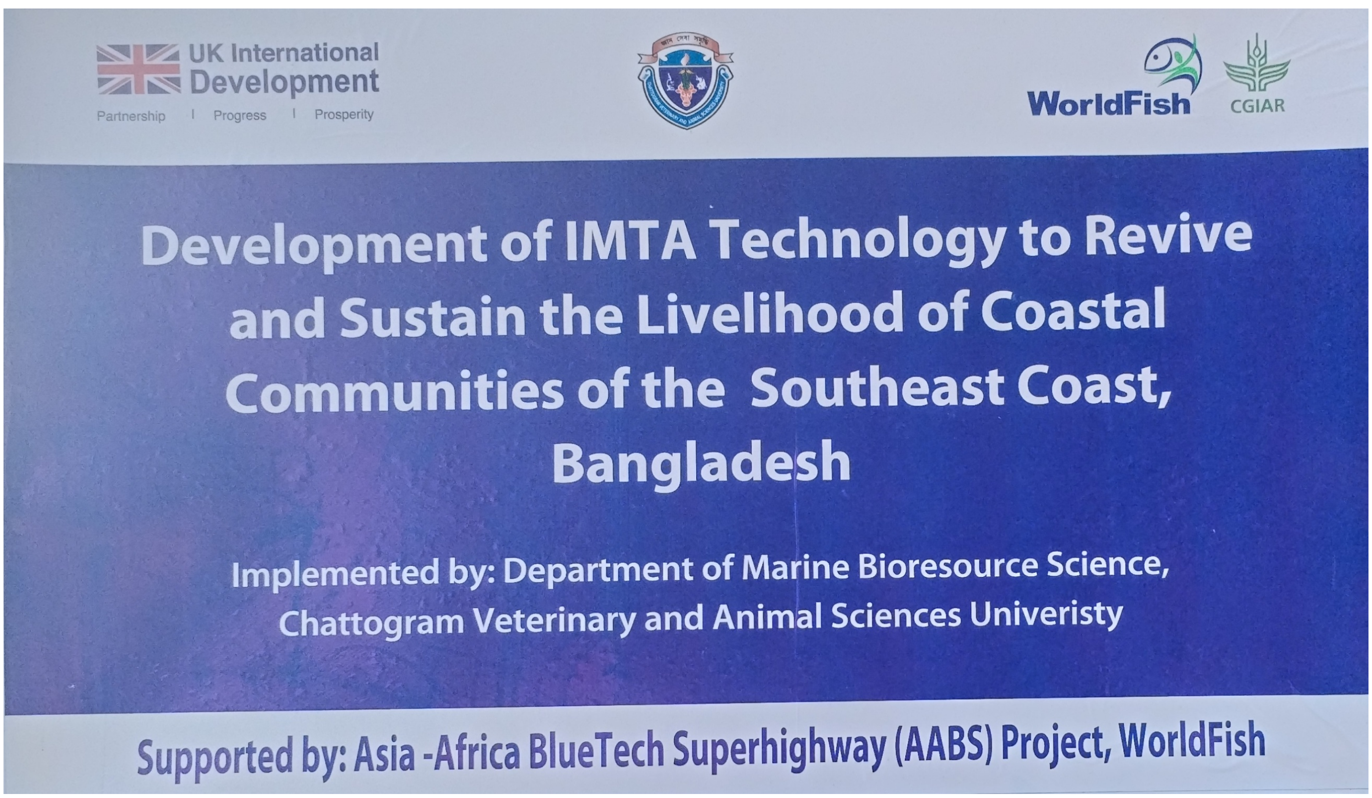


Fig: Internship Project Overview.

2.Methods and Methodology

2.1 Study area

The internship was mainly conducted in the Cox's Bazar region of Bangladesh in three different types of environments, including a hatchery, a pond-based system, and an open-water Integrated Multi-Trophic Aquaculture (IMTA) site. We conducted the hatchery-based activities at Chattogram Veterinary and Animal Sciences University (CVASU), located in Dorianagar, Cox's Bazar. The second study site was a pond-based aquaculture system in Khuruskul Uttarpara, Cox's Bazar, a region well known for its extensive fisheries and aquaculture operations. The open-water IMTA site was in the Moheshkhali and Bakkhali channels, two ecologically significant coastal water bodies of Bangladesh. Moheshkhali Channel, a tidal waterway separating Moheshkhali Island from the mainland, is characterized by strong tidal currents, making it an ideal location for suspended aquaculture systems, such as seaweed and shellfish farming (Islam et.al..2018).

Fig: 2 - Site of IMTA in Cox,s Bazar Region.

2.2 Species selection:

Three types of species were chosen for Integrated Multi-Trophic Aquaculture (IMTA) in hatcheries and open water during this study: *Gracilaria spp.* (seaweed), *Perna viridis* (green mussel), and *Mystus gulio* (also known as Nona Tengra or the Long-Whiskered Catfish in some places).

1.seaweed (*Gracilaria spp.*): The study selected the Gracilaria spp. (red algae) as the best species due to its ecological and economic significance, as well as its sustainability. Furthermore, it produces important products such as agar (Abreu et al., 2011). This seaweed is mainly found in the estuaries and intertidal zone, which makes it suitable for the IMTA in the Bangladesh coastal area (Buschmann et al., 2001; Biswas et al., 2019). *Gracilaria spp.* demonstrates the ability to adapt to various conditions, exhibiting rapid growth and a dual reproductive strategy (Abreu et al., 2011), making this species suitable for large-scale cultivation. Additionally, this species can tolerate fluctuations in salinity and can be cultivated in moderately saline water, further enhancing its suitability for diverse aquaculture systems (Irisarri et al., 2015; Ahmed & Glaser, 2016).On the other hand, this species also has some environmental benefits, including helping to mitigate excess nutrients from the environment and absorbing aquaculture effluents (Troell et al., 2009; Buschmann et al., 2001). This species has not only economic value but also contributes to environmental activities, like helping to produce oxygen and carbon sequestration and also giving habitat for the juvenile and herbivorous fish (Ryther et al., 2006). By fostering biodiversity in their ecosystems, they play a crucial role in maintaining the balance of marine life, which ultimately supports the livelihoods of communities that rely on these resources (Hossain et al., 2022).Therefore, we can conclude that Gracilaria spp. are essential for sustained aquaculture, providing both ecological and economic advantages.

2.Green mussel (*Perna viridis):*The major purpose of the IMTA is related to the rapid growth of species with their economic value; the green mussel (*Perna viridis*), which has these characteristics, is chosen as the species for the aquaculture. The green mussel (*Perna viridis*) mainly inhabits the Indo-Pacific region, where it can tolerate the brackish water quality as well as adapt to the marine environment. Additionally, the green mussel is known for its high growth rates and ability to filter large volumes of water, contributing positively to the ecosystem by improving water quality. For this reason, this species is chosen as the suitable IMTA species for the coastal ecosystem of Bangladesh, including the Cox's Bazar region (Ahmed & Glaser, 2016; Biswas et al., 2019). The green mussel also has the ability of biofiltration. In an aquaculture system, when the waste is produced by other organisms in the water, the green mussel captures this extra waste material for their growth, which is also helpful for the environment because it also makes the water clean. In IMTA systems, mussels are cultivated with seaweeds (Gracilaria spp.) and fish to maintain the nutrient cycle (Abreu et al., 2011; Biswas et al., 2019).We selected the green mussel as a species for IMTA due to its low cost, high protein value, and high export possibilities (Kibria & Haque, 2018). Furthermore, it requires minimal feed compared to the other species (Ahmed & Glaser, 2016). They can adjust with the temperature and salinity fluctuations, which makes them a great species for aquaculture for cyclone-prone regions like Cox's Bazar (Hossain et al., 2022).

3. Nona Tengra (*Mystus gulio):* Mystus gulio is a euryhaline species that inhabits estuarine and tidal environments and can adapt to salinities ranging from freshwater to 19.8 ppt (Kumar et al. 2019, cited in Hossain et al. 2021).This species' adaptability makes it suitable for aquaculture in Cox's Bazar, particularly in areas where salinity intrusion may occur due to sea-level rise(Ahmed & Glaser 2016; Hossain et al. 2021).This species's ability to resist salinity in dynamic coastal ecosystems makes it an IMTA species for ponds, rivers, and open water cages(Biswas et al. 2019; Hossain et al. 2021).The food habitat of the M. gulio is insects, diatoms, algae, and debris (Begum et al. 2008). This species also has some environmental benefits; it reduces eutrophication and improves water quality by eating organic particles and benthic species (Abreu et al. 2011; Troell et al. 2009). Along with extractive species like seaweeds (Gracilaria spp.) and filter feeders like oysters and mussels, this secondary consumer keeps the nutrient cycle in balance (Hossain et al. 2019).The salt tolerance, ecological adaptability, economic worth, and compatibility with climate-resilient practices of Mystus gulio make it a strategic choice for IMTA in Cox's Bazar. In a location where climate change is becoming a more pressing concern, its incorporation into multi-trophic systems improves sustainability, resource efficiency, and livelihood security.

3.Data collection:

3.1.Water Quality Data:

Weekly, we collect the water quality data from three different locations.

parameters measured:

1.Water temperature

2. Salinity

3.PH

Instrument that is used for the data collection:

We primarily use water multiparameters and CTD to measure temperature, while we use a handheld refractometer to measure the salinity.

Sampling Locations: Hatchery,Pond ,Open aquacultur.

Sampling Frame : From December 30 to January 31 (2025).

Fig 3 - Data collection by using CTD from the open Water IMTA System.

Fig-4 We collected seaweed samples from three different locations (hatchery, pond, and open aquaculture area) once a week.

Fig 5: Three Different Fish Nona Tengra (*Mystus gulio)* Cultures *(Pond Culture, HatcheryCulture, and Open Water Culture).*

Fig 6: Three Different Green mussels Cultures Green mussel (*Perna viridis) (Pond Culture, HatcheryCulture, and Open Water Culture).*

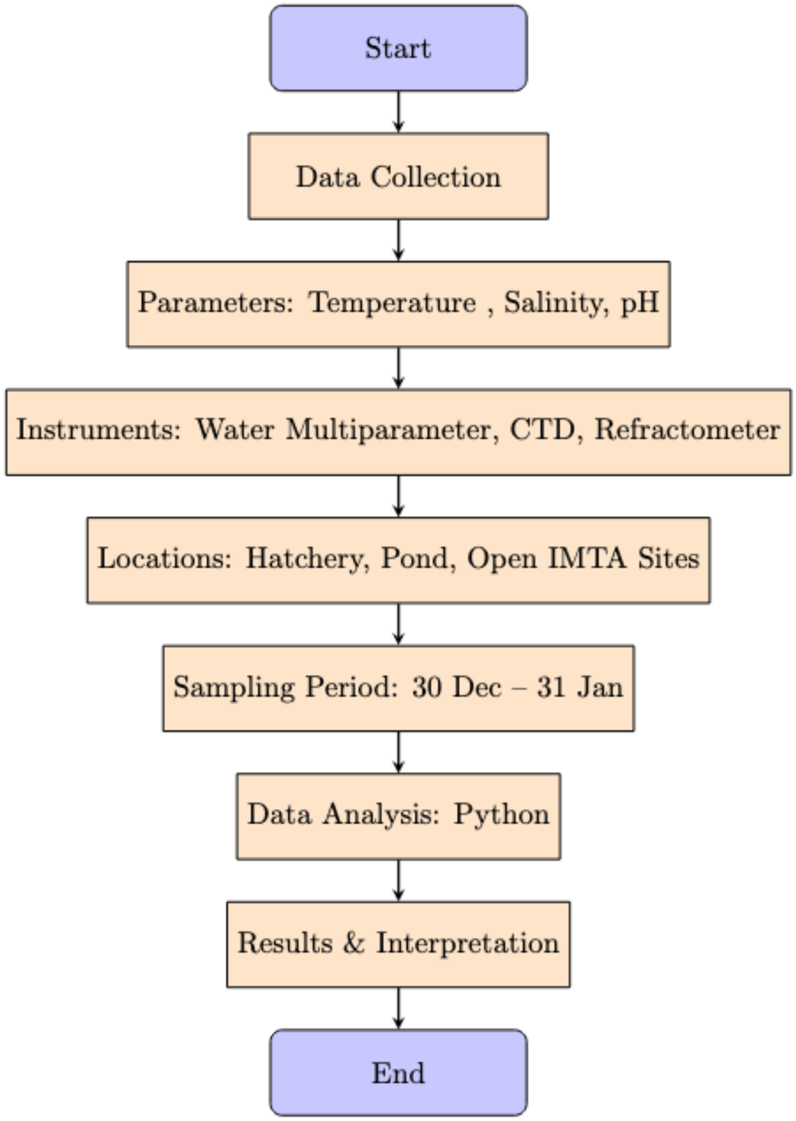


Table 1: Flow Diagram of the Methodology for the Study.

Result

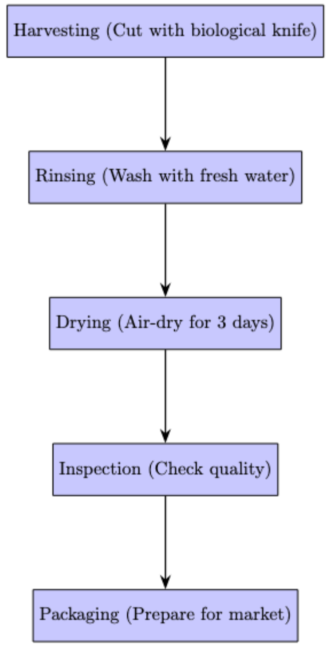
4.1 Different Culture Techniques of Seaweed

Coastal seaweed Auqculture: Mainly we observed traditional seaweed aquaculture, which is known as bamboo and rope, during our study. For better growth and productivity, this region is selected as the best area for the seaweed culture because there is appropriate water quality, enough sunshine, and moderate waves in this area, which makes this area the best for the seaweed culture. This aquaculture site uses bamboo as its infrastructure, securing the seaweed seedlings tightly to the water's surface. Bound tightly to the ropes, these plants develop by drawing nutrients from the nearby waters. The harvesting usually takes place once a month. Farmers carefully clip ripe seaweed off the ropes with their hands and Following harvest, the seaweed is cleaned in freshwater or seawater to eliminate trash before being driven to markets or processing facilities. Next, the sunlight dries the seaweed for commercial market supply.

Table 1: Difference Chart for Seaweed Culture Techniques

Feature	**CVASU Hatchery**	**Khurushkul Pond**	**Bakkhali-Moheshkhali Channel**
Environment	Highly controlled tank environment	Semi-controlled pond environment	Natural open water environment
Support Structure	Seaweed (Gracilaria) suspended on rope	Bamboo floats with drum buoyancy system	Bamboo-float rope system (natural channel)
Water Flow & Oxygen	Regulated oxygen concentration with moderate flow	Partial natural pond flow with managed buoyancy	Fully natural tidal flows
Floating Mechanism	Tank suspension system	Drum-bamboo float combination	Natural buoyancy in channel waters
Level of Management	High-intensity parameter control	Moderate infrastructure management	Minimal intervention (natural systems)

Flow Diagram-2 for Harvesting Seaweed from the Natural Environment of Moheshkhali Area



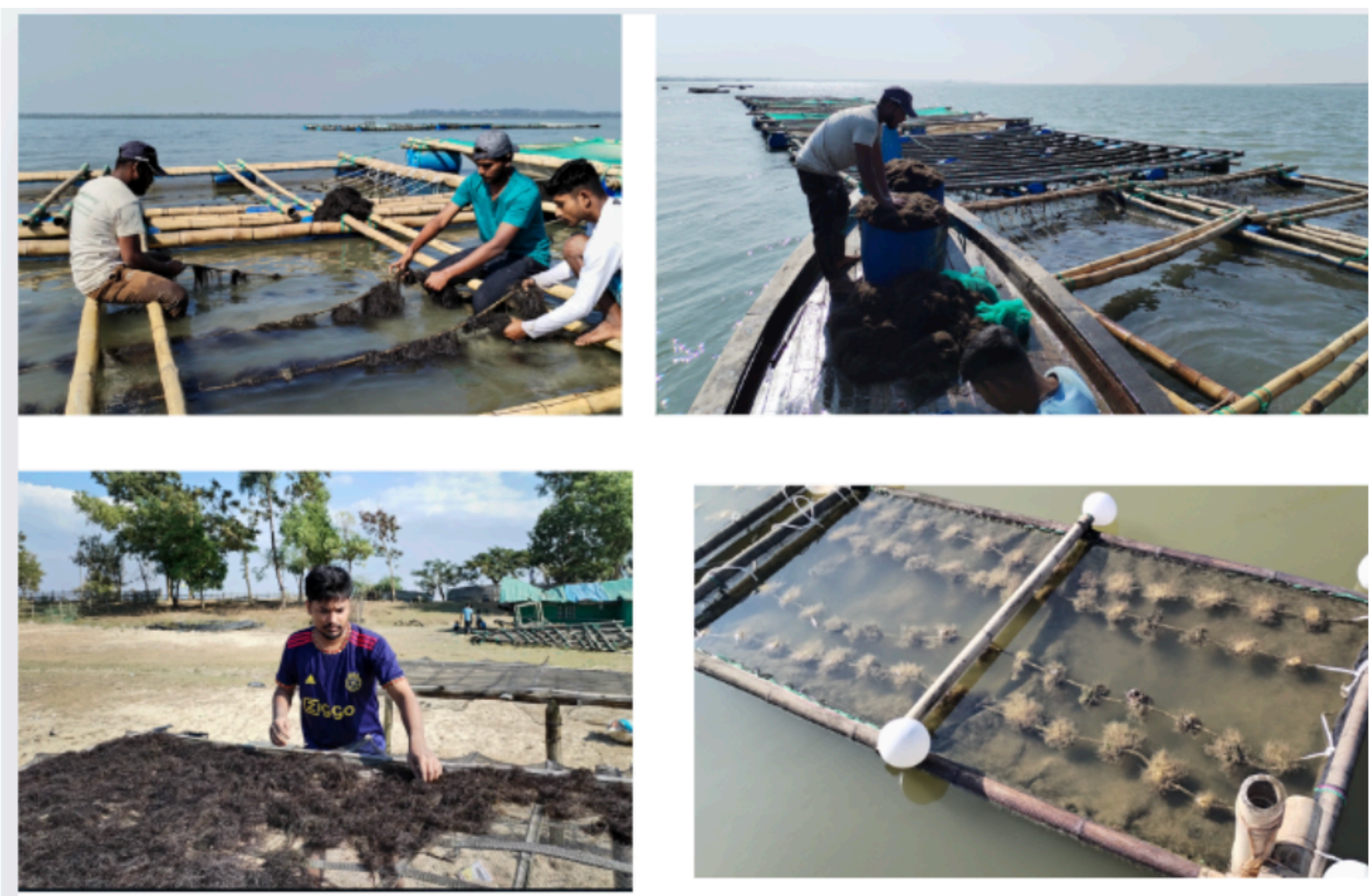


Fig 7: Open Water Culture techniques of the Sea weed.

Pond sea weed aquaculture :
We see the cost-effective modular bamboo constructions with (10x4x2 ft) placed into the pond to maximize the water flow and also for the light exposure in pond-based seaweed aquaculture. Each structure contains 8–10 ropes, and each rope contains 10–12 seeds of Gracilaria spp. We used PVC pipes and drums to support the structure, which improved its buoyancy. Paddlewheel aerators help preserve water circulation in the pond area.

Hatchery sea weed aquaculture:

In the system for cultivating seaweed in hatcheries, the seaweed is hung by the ropes in a controlled environmental tank. An artificial wave generator controls water flow so as to guarantee ideal growing conditions. We change the water twice a month to keep it clean, prevent microbiological infections, and maintain the nitrate level.

Water Quality of sea weed in both open aquacultur, pond and Hatchery area:

1.Temperature: (Fig-8 Changes of temperature of three different culture methods)

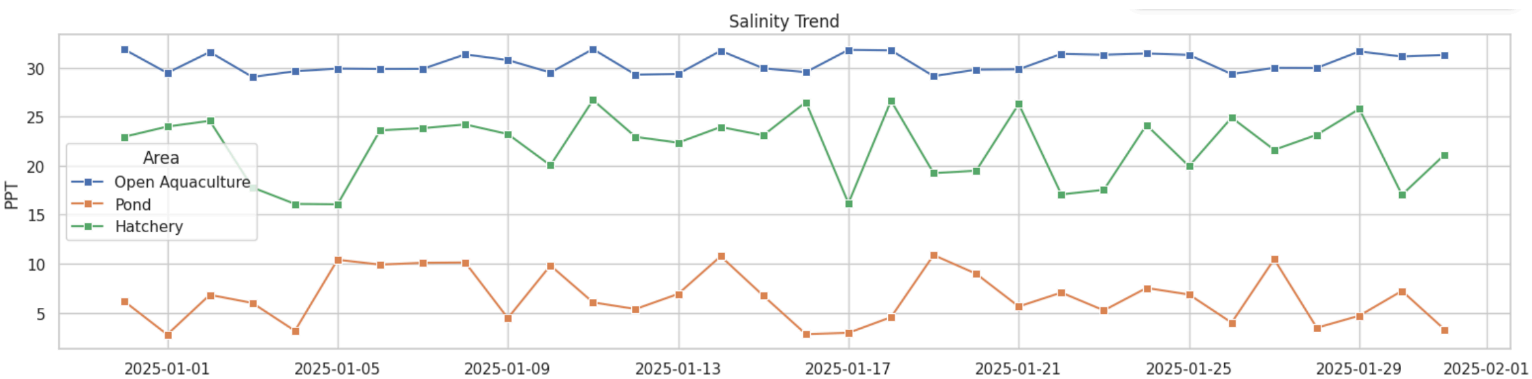
The temperature data from the three IMTA culture systems—Hatchery, Pond, and Open Aquaculture—highlight distinct environmental characteristics. Hatcheries recorded the warmest and most stable temperatures, with an average of 24.15°C and a narrow range (23.48°C to 24.66°C). This consistency is due to the use of heaters and a controlled environment, making hatcheries ideal for maintaining optimal thermal conditions.

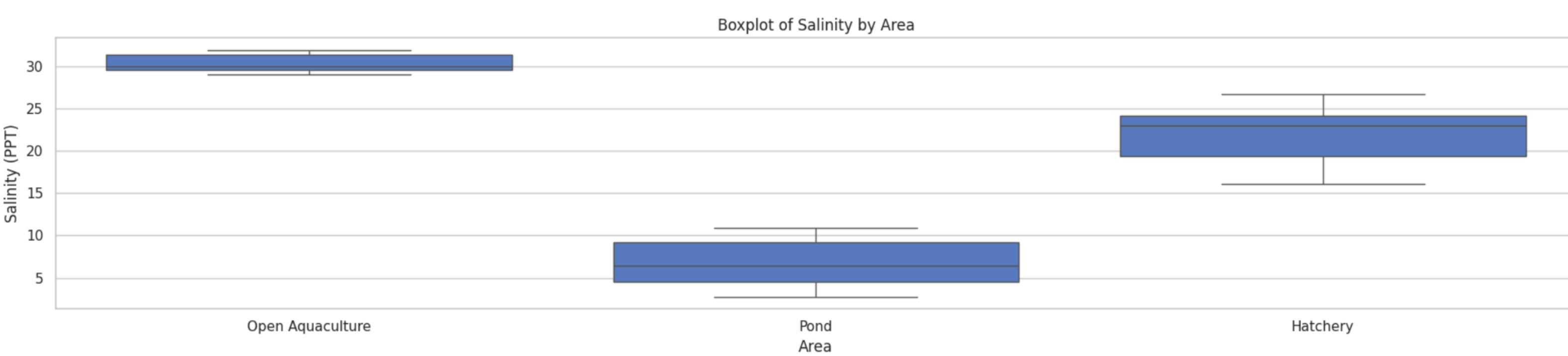
In contrast, the Open Aquaculture system had the lowest average temperature at 22.82°C, with very minimal fluctuations (22.50°C to 23.18°C). This thermal stability is likely due to continuous seawater exchange, which naturally buffers temperature changes.

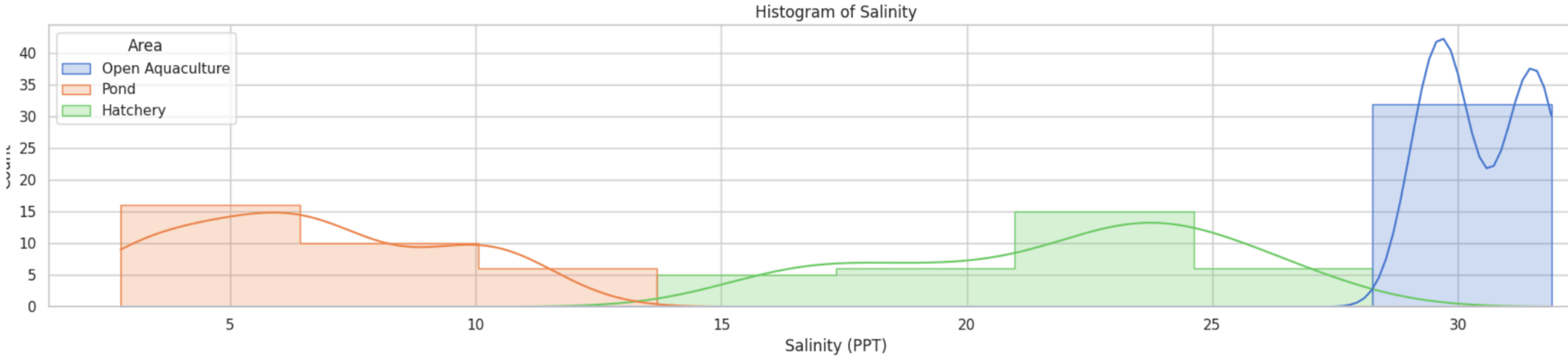
The Pond system fell between the two, with an average temperature of 23.41°C and a wider range (22.87°C to 24.00°C), reflecting its exposure to environmental factors like sunlight, wind, and air temperature.

In summary, hatcheries provide the warmest and most controlled conditions, ponds are more influenced by daily and seasonal environmental changes, and open aquaculture maintains a cooler yet stable environment due to natural seawater flow.

2. Salinity:(Fig -8 Changes of salinity for the three different culture)





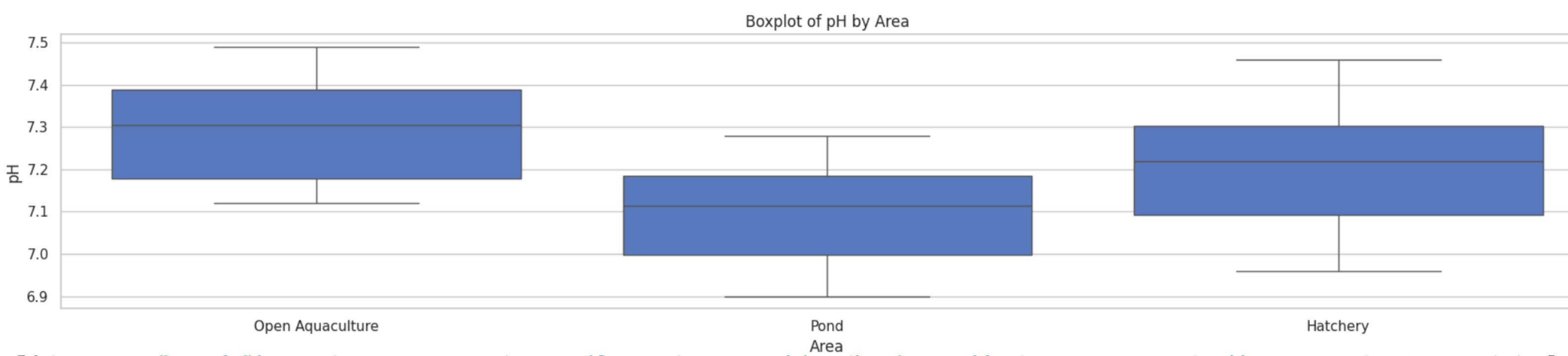


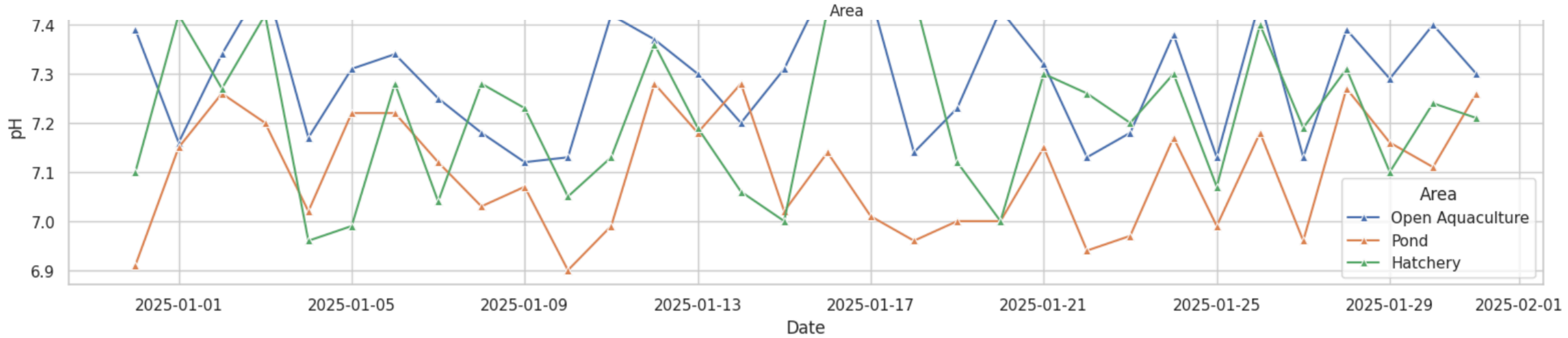
The Open Aquaculture area showed the highest and most consistent salinity, averaging 30.50 ppt with only slight variation (29.06 to 31.90 ppt). This stability reflects the natural conditions of the sea, where continuous water exchange keeps salinity levels steady.

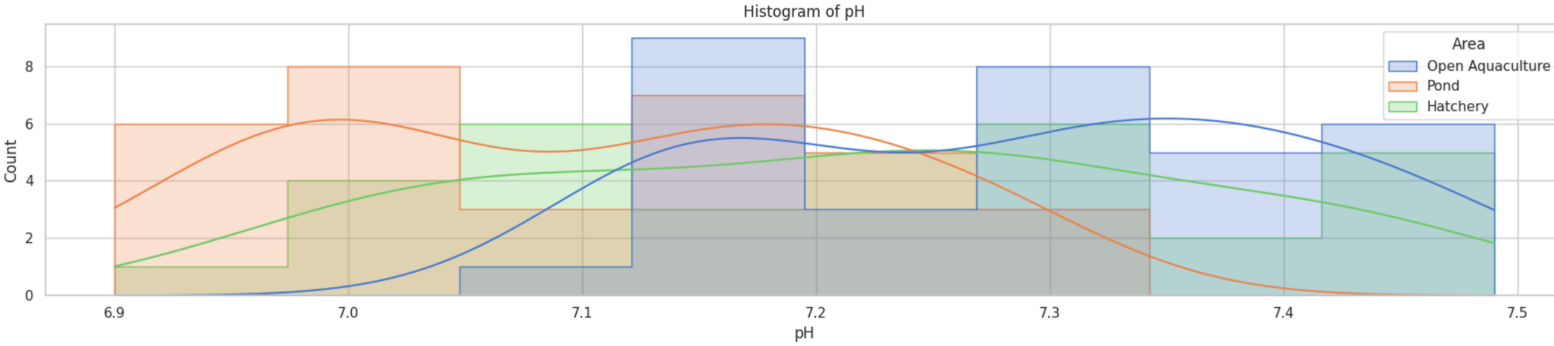
In contrast, the Hatchery environment had a moderate salinity average of 21.94 ppt but showed greater variability (16.06 to 26.70 ppt). This fluctuation is likely due to the manual mixing of seawater and freshwater to maintain optimal conditions for cultured species.

The Pond system recorded the lowest average salinity at just 6.59 ppt, with a wide range from 2.77 to 10.88 ppt. Such variation suggests that pond salinity is strongly influenced by rainfall, evaporation, and limited water exchange.

3.PH:(Fig-10 changes of the three different culture method)







Open Aquaculture exhibited the highest and most stable pH, averaging 7.29, with a narrow range from 7.12 to 7.49 and a low standard deviation of 0.12. This consistency suggests a naturally buffered marine environment, where continuous seawater exchange maintains pH balance and minimizes fluctuations.

The Hatchery system had a slightly lower average pH of 7.21, with readings ranging from 6.96 to 7.46 and a standard deviation of 0.15. Although still stable, these values reflect a controlled setup that might see occasional adjustments in water chemistry due to water treatments or biological activity.

Meanwhile, the Pond system recorded the lowest average pH at 7.10, with a broader range of 6.90 to 7.28 and a standard deviation of 0.12. This points to more variability and a subtle tendency toward lower pH, possibly driven by organic matter buildup, respiration, or limited water exchange.

Conclusion:

In this study, I explored the potential of Integrated Multi-Trophic Aquaculture (IMTA) systems in Cox's Bazar, Bangladesh, across open-water, pond, and hatchery settings. The findings highlight how IMTA can enhance both ecological sustainability and economic resilience in coastal aquaculture. By combining Gracilaria spp. (seaweed), Perna viridis (green mussel), and Mystus gulio (locally known as Nona Tengra), these systems efficiently recycle nutrients, reduce environmental waste, and offer diverse aquaculture outputs.

Among the three environments, open-water setups—with stable salinity (30.50 ppt) and pH (7.29)—proved especially favorable for seaweed and mussel growth. Ponds, on the other hand, showed that Mystus gulio can adapt well to fluctuating conditions, while hatcheries, where the temperature was maintained around 24.15°C, provided an ideal environment for optimizing seaweed cultivation.

Although some challenges remain, such as infrastructure limitations and gaps in technical knowledge, IMTA stands out as a promising and scalable approach. With proper investment in storm-resilient systems, hands-on training for farmers, and supportive policy frameworks, IMTA could play a key role in reducing environmental impacts, boosting food security, and supporting coastal livelihoods—especially in climate-vulnerable regions like Bangladesh.

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