Enhancing Aquaculture Sustainability through AI-Powered Precision Farming - The APY Tool

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Abstract (500 Words)

Aquaculture has been a growing industry in the past decade. In the context of India and Indian ocean region, aquaculture holds a significant value as India has remained one of the top exporters of fisheries and frozen shrimp worldwide. A lot about the growth of aquaculture in a region (i.e. its feasibility and challenges) can be found from thorough study of the water bodies and their quality in that region.

In response to the growing need for efficient underwater data collection in aquaculture ponds in India, our project aims to develop IoT sensors tailored for this purpose. **Historically**, underwater data collection in aquaculture ponds has been limited, hindering the ability to monitor and manage ponds effectively. While a lot of technology regarding remote agricultural monitoring have been developed and deployed in the west. Even there are vendors available in countries like China, Vietnam and Indonesia that produce and export these sensor sets, but we are pitching to solve this problem by developing *made in India* sensor sets from indigenous hardware.

Our proposed solution involves designing and implementing a network of IoT sensors capable of collecting various data points such as water quality parameters, temperature, pH levels, and oxygen levels, and few other parameters.

The **vision** is to revolutionize aquaculture pond management by providing real-time, accurate, and comprehensive data insights. Our goals include enhancing the efficiency and productivity of aquaculture operations, improving environmental sustainability, and reducing operational costs with fully functional APY (Area, Production, Yield) Tool platform, integrating real-time IoT sensor data with user-friendly dashboards for data visualization, advanced analytics, and actionable insights tailored for small-scale aquaculture operations.

Building upon the successful development and field validation of the APY Tool, Nirdhwani Technologies (NDT) will focus on scaling and deepening its impact through expanded deployment and integration of indigenous IoT-based monitoring solutions. A key priority is the integration of real-time environmental sensors to further enhance predictive accuracy and automation in aquaculture management. NDT also aims to establish robust backend protocols and infrastructure that can support seamless data transmission, secure storage, and real-time analytics, thereby enabling data-driven pond management across India's coastal belt.

What sets NDT apart is its **Made-in-India approach**—from sensor design to app

interface—tailored for Indian farming conditions. The system supports **regional languages**, works on basic smartphones, and is developed on an **open, modular architecture** that promotes continuous learning through user-reported outcomes.

The ultimate goal is to create a replicable and sustainable model that harmonizes technology with traditional knowledge, strengthens rural aquaculture livelihoods, and contributes meaningfully to India's Blue Economy goals.

Background (500 Words)

Aquaculture, the practice of breeding, rearing, and harvesting of aquatic organisms in all types of water bodies. The influence of aquaculture in the Indian Ocean region is profound, shaping both economic prosperity and environmental sustainability. With its vast coastline and abundant marine resources, countries in the Indian Ocean region, especially India, have increasingly turned to aquaculture as a means of meeting growing demands for seafood and generating revenue.

The one thing that still plagues this tremendous growth potential is the low aquaculture productivity in Indian aquaculture systems which is highly attributed to lack of skill among farmers, a highly varying climate profile and a lack of dissemination channels to guide farmers towards optimal production levels.

A lot of effort has been gone in this aquaculture space to optimize productivity levels, like development of biofloc systems, introduction of Integrated Multi-trophic aquaculture, skill training programs for small aquaculture owners, and devising intensive cultivation techniques, etc. While all this solution broadly covers how one can improvise their practice it doesn't really track their effectiveness at the large scale.

The APY (Area, Production, Yield) Tool bridges this gap by transforming how farmers interact with their farms. Unlike standalone IoT systems that only monitor water parameters, the APY Tool integrates AI-powered analytics, historical trends, and government extension services into a single, farmer-friendly platform. It goes beyond real-time monitoring—predicting disease outbreaks, optimizing feed schedules, and even linking farmers to subsidies and credit based on their farm's digital footprint. By harnessing technology to monitor and manage aquaculture operations, countries can enhance productivity while minimizing negative environmental impacts. These Tool enable precise monitoring of water quality, ensuring *optimal conditions for aquatic life*.

Research efforts show that a set of water parameters truly determine the growth of the breeding culture in it. This set broadly includes Temperature, water salinity, water Ph, Dissolved Oxygen level in water, TAN, Dissolved nitrates, etc. while IoT Sensors can track this data to determine how favorable is the water for the culture of certain aquatic organism, the APY Tool transforms raw measurements into actionable intelligence for farmers. The APY Tool's AI engine analyzes sensor data against species-specific growth models, providing clear recommendations. This solution can work in addendum to the existing research and technology, and can help remote management of the farms.

However, the success of such digital interventions hinges not just on technological accuracy but also on their usability, affordability, and acceptance at the grassroots. Many aquaculture stakeholders—especially women, youth, and marginalized communities—remain excluded from the digital shift due to language barriers, low digital literacy, and the absence of localized training. To truly transform the sector, it is essential to embed user-centered design principles into these innovations and build strong feedback loops between field realities and digital platforms. The APY Tool, with its multilingual interface, modular design, and compatibility with low-cost smartphones, is strategically positioned to bridge this last-mile gap and become a catalyst for equitable digital transformation in India's fisheries sector.

Problem Statement (600 Words)

Problem statement: Develop and deploy the APY Tool—an AI-powered precision farming platform that integrates real-time data from compact, energy-efficient underwater sensors to monitor key aquaculture parameters (temperature, salinity, dissolved oxygen, pH, and more). The APY Tool will deliver actionable insights, predictive analytics, and digital record-keeping to empower small-scale fish farmers in India, enhance productivity, support sustainable resource use, and improve resilience to environmental and operational challenges.

Importance of Problem: India is topping charts as a leading exporter of high-quality frozen shrimp to the U.S. and is the second largest exporter of fisheries globally. Over time, as natural habitats have been depleted due to illegal and unregulated fishing, aquaculture has become the primary source of fisheries. As evident from the numbers, aquaculture in India mainly caters to the demand for shrimp, seaweed products, and certain fish species.

To contextualize the innovation presented by NDT, it is important to understand the scientific basis underpinning the Area Production Yield (APY) Tool and its role in advancing precision aquaculture. Drawing from a strong foundation of peer-reviewed literature and domain expertise, the APY Tool is designed to enable real-time monitoring and predictive management of critical water quality parameters—namely temperature, stocking density, pH, salinity, and dissolved oxygen. These parameters are fundamental to ensuring both high survival rates and optimal biomass output in aquaculture systems.

Research-backed thresholds suggest that water temperature should ideally range between 27°C to 33°C to support acclimatization during the post-larval (PL) stage of Vannamei shrimp, thereby minimizing stress and improving survival. Stocking density, while influencing total biomass, must be managed carefully; overcrowding can reduce individual growth rates and increase feed demands, compromising the economic and ecological efficiency of the operation. pH levels should be maintained slightly above neutral, ideally between 7.0 and 8.0, to avoid adverse effects from sludge accumulation and ammonia toxicity.

Salinity is another critical parameter, with studies indicating that a range of 20–30 ppt (typical of brackish water) supports superior shrimp growth and nutrient uptake. India's vast brackish water reserves make this particularly relevant. Lastly, dissolved oxygen (DO) levels should be kept above 5 PPM, as oxygen is essential for metabolic processes and overall shrimp vitality. This can be maintained through aeration and appropriate water management practices.

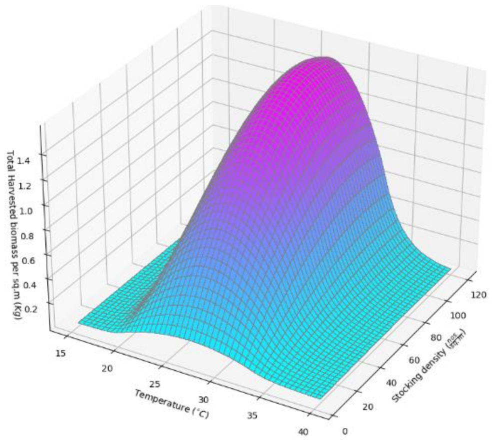
The APY Tool leverages AI-driven models and low-cost sensor networks to not only track these variables in real time but also provide farmers with predictive insights and actionable recommendations. By translating complex environmental data into user-friendly guidance, the tool empowers small and marginal farmers to make timely, data-informed decisions. This not only enhances productivity and product quality but also reduces resource inputs and supports long-term environmental sustainability.

Despite the availability of advanced tools globally, the Indian aquaculture sector has been slow to adopt precision farming technologies at the grassroots level. Most small and marginal farmers still rely on traditional practices due to a lack of awareness, affordability constraints, and poor access to digital infrastructure. High-end sensor systems from countries like China and Indonesia are often cost-prohibitive, language-incompatible, or unsuitable for Indian water conditions. This creates a technology disconnect—where the science exists, but localized, accessible solutions do not. The APY Tool addresses this critical adoption gap by offering an intuitive, multilingual platform supported by low-cost, indigenous sensor technology, tailored specifically for the Indian aquaculture ecosystem.

In doing so, NDT bridges a critical technology gap in India's aquaculture sector—offering a scalable, affordable, and inclusive solution that aligns with national priorities under Digital India, Blue Economy, and Atmanirbhar Bharat.

2.1 Current Progress (1500 Words)

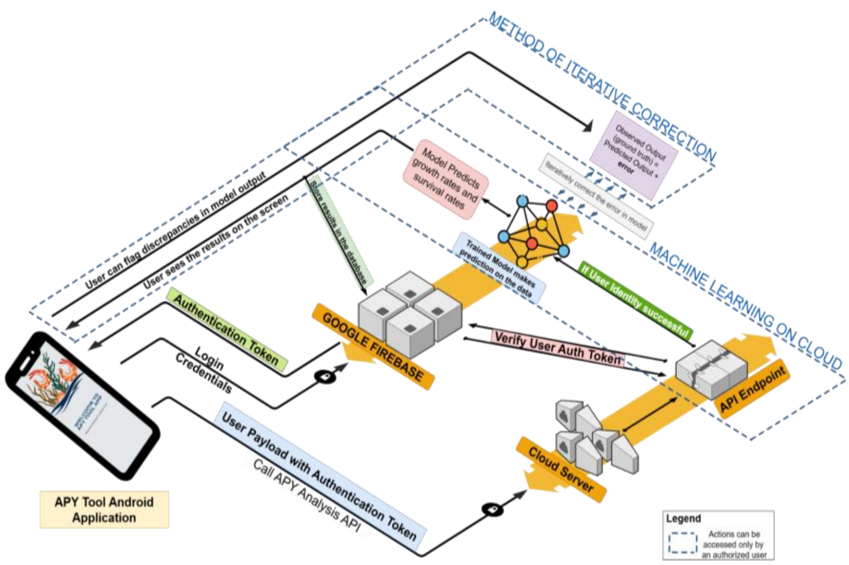
<u>Digital Innovation- APY Tool Deployment and Technological Validation</u>: NDT has emerged as a key innovator in the digital transformation of India's aquaculture sector through the development and deployment of **APY Tool**. This Android-based application represents a critical step toward modernizing traditional aquaculture practices in alignment with national missions such as **Digital India** and the **Blue Economy Policy**. Unlike conventional, experience-based farming methods, the APY Tool leverages **AI-driven predictive analytics** to offer farmers real-time insights based on environmental parameters such as **temperature, salinity, pH, stocking density, and dissolved oxygen**. With predictive accuracy reaching up to **95%**, the tool enables optimized decisions on feeding schedules, harvest planning, and risk mitigation, significantly improving productivity and sustainability.



The above graph shows the variation in shrimp biomass as influenced by temperature and stocking density, incorporating the impact of varying survival rates.

NDT's innovation sets India apart in the global aquaculture ecosystem, especially when compared to countries like China, where technological advancement is focused primarily on industrial-scale operations. In contrast, NDT's APY Tool is designed with inclusivity in mind, **democratizing access to precision farming** for India's small and marginal aquafarmers. The tool's **open architecture, mobile accessibility**, and **iterative learning feature**—which allows users to input actual farm results for model refinement—create a dynamic feedback loop that enhances the tool's performance over time.

Comprehensive System Architecture of the APY Analysis Tool:



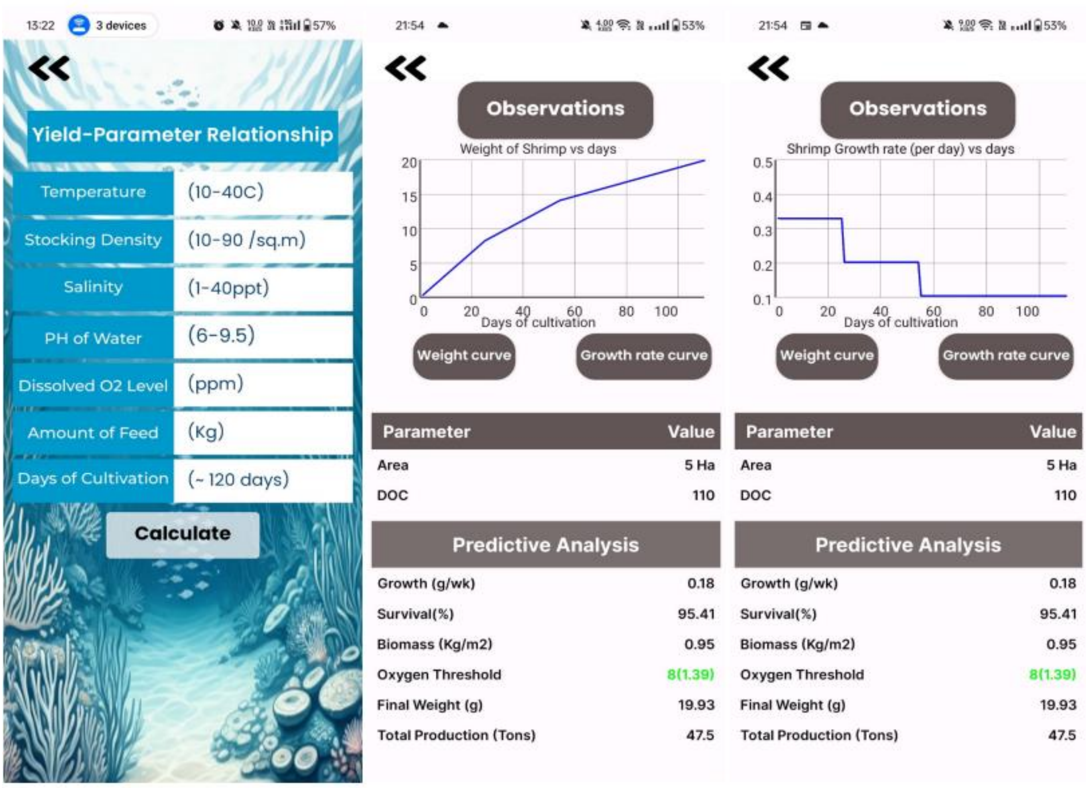
This **bottom-up design philosophy** ensures that technology adapts to local realities rather than imposing top-down solutions, which are often ill-suited to India's decentralized aquaculture sector.

Device specifications for the testing of the APY Tool:

Attribute	Specification
Compile SDK Version	34
Target SDK Version	33
Java Compatibility	Java 8
Main Dependencies	Volley, Firebase Auth/Database, GraphView, Lottie
Test Device Model	OnePlus Nord CE 4
OS Version	Android 14
Processor	Qualcomm Snapdragon 7 Gen 3
RAM	8 GB
Storage	128 GB
Testing Tools	JUnit, Espresso

Below fig. shows the User Interface of the Shrimp APY Tool:

a. Input screen for key environmental parameters such as temperature, stocking density, salinity, pH, dissolved oxygen, and cultivation duration.
b. Output screen displaying yield predictions along with a dynamic graph illustrating shrimp weight vs. cultivation days.
“Growth Rate Curve” feature that enables weekly monitoring of growth trends (in grams/week) to support informed farm management decisions.



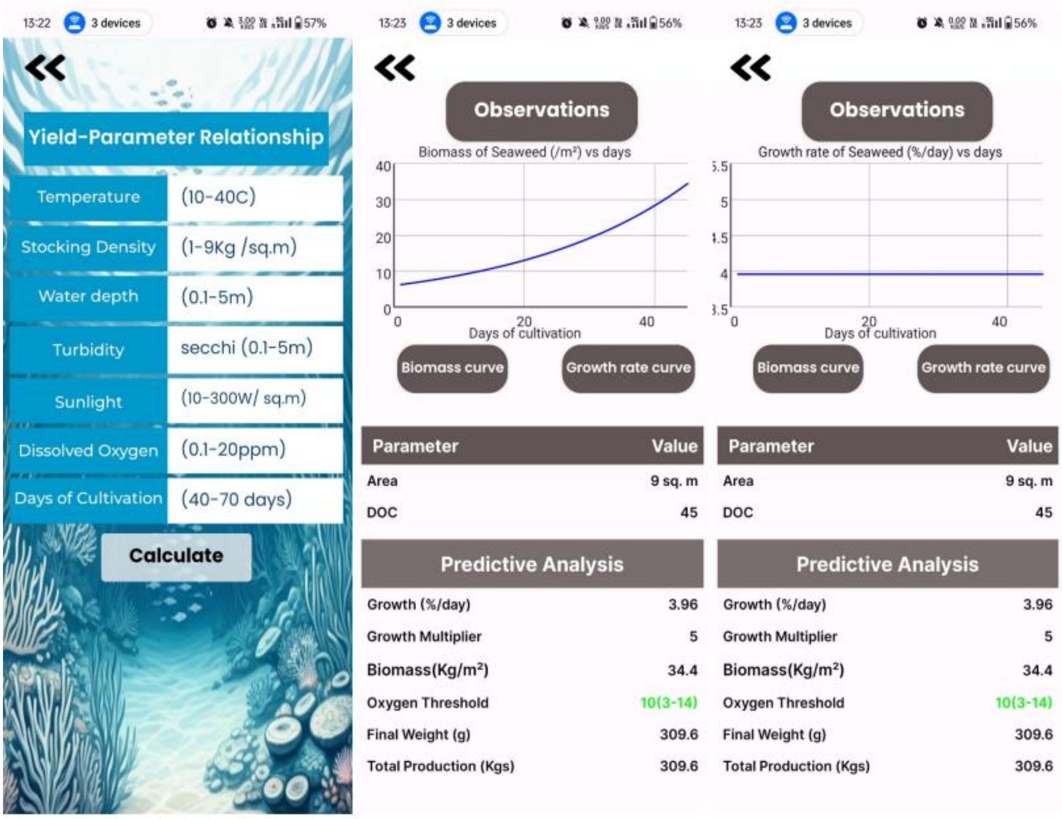
(a) (b) (c)

Below Fig. shows the seaweed section of APY tool:

a. Main screen for inputting farm environmental parameters (e.g., water temperature, seed stocking density, water depth, turbidity, sunlight, dissolved oxygen, and cultivation days)

b. Predictions with a graph of seaweed biomass vs. cultivation days.

c. "Growth Rate Curve" feature to track daily growth rate (%/day) variations throughout the cultivation period.



(a) (b) (c)

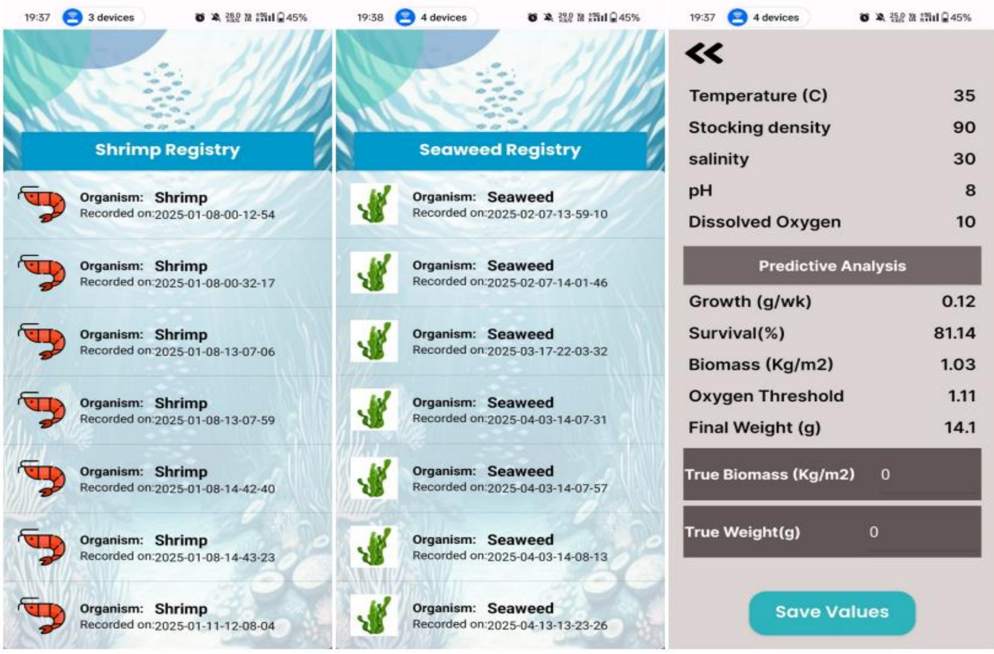
On the backend, the APY Tool integrates Python-based regression models deployed via **Flask APIs** and hosted on **PythonAnywhere**. The app supports input of water quality parameters and returns yield predictions in structured JSON format. Farmers can view past entries and provide ground-truth data—such as actual biomass and final weight—to further refine predictions.

Below Fig. shows the Registry Section of the APY Tool:

a. Shrimp registry tracking the user's history with the shrimp APY Tool.

b. Seaweed registry tracking the user's history with the seaweed APY Tool.

c. Option for users to report observed biomass and final weight to update and retrain the model with new data.



(a) (b) (c)

This modular, scalable system architecture has laid the foundation for future enhancements, including integration with indigenous IoT sensor networks for continuous, real-time monitoring.

Community Engagement- Field Validation and Social Integration: As part of its sustained efforts to promote inclusive innovation and community-driven digital transformation, the NDT undertook a strategically planned ***field engagement*** in Veraval, Gujarat—one of India's key coastal hubs for aquaculture and seaweed farming. This visit had a dual purpose: to validate the APY Tool in dynamic, real-world farming environments, and to build trust-based partnerships with the fishing and seaweed cultivating communities. The engagement aligns with national programs such as Digital India, Skill India, and the Blue Economy Policy, by actively bridging the gap between advanced technological solutions and local livelihood systems. During the visit, the APY Tool was demonstrated to small and marginal fishers and seaweed farmers through interactive, boat-based sessions and village-level meetings. These demonstrations enabled real-time user feedback, allowing NDT's technical team to refine the tool based on practical constraints and environmental nuances specific to the region.

The field visit also served as a deep listening exercise to capture the socio-economic realities and challenges of coastal households. Discussions revealed that while smartphone ownership was relatively high, the cost of data recharges remains prohibitive, and technical literacy—especially among older fishers and women—is limited. Internet access, though present, is often unreliable in remote coastal stretches. Additionally, there was an expressed lack of institutional support, particularly in the absence of subsidies beyond diesel fuel, and no formal mechanism for minimum support pricing or post-harvest storage.

Demography and Gender-wise participation in fisheries activities based on the responses of the respondents in the ground survey

Category	Shreyansh Sikotariya	Ravi Kotiya	Kaushik Nanjibhai Solanki	Jignesh	Visiha Haribhari
Age	25	32	25	25	26
Level of Education	Graduate	12th Pass	Graduate	12th Pass	Graduate
Access to Credit	1 Lakh to 5 Lakh	50,000 to 1 Lakh	50,000 to 1 lakh	More than 5 Lakh	More than 5 Lakh
Women Participation	High	Medium	Low	Medium	Low
Women's Primary Activity	Processing of Seafood	Marketing of seafood	Others	Processing of Seafood	Others
Women's Challenges	Social Barrier	Limited access to financial Resource	Time Burden	Lack of Training	Limited access to financial Resource
Barrier to Tech (if yes, give reason)	Due to High Cost	Due to High Cost	Due to High Cost	Lack of Technical Skills	Due to High Cost

Women play a central yet undervalued role in seafood processing and marketing, but face multiple systemic barriers, including lack of access to finance, training opportunities, and pervasive social constraints.

Environmental vulnerabilities such as the unpredictability of monsoon seasons and concerns over the theft or damage of sensors placed in the open marine environment were significant insights. Despite these barriers, the community responded with enthusiasm to the APY Tool's core predictive features, especially its ability to generate yield estimates using variables like salinity, temperature, and stocking density. These matched well with traditional knowledge systems, where fishers already use refractometers and pH meters to make manual estimations.

Fisheries production and other business-related details of the fishermen involved in the ground survey

Category	Shreyansh Sikotariya	Ravi Kotiya	Kaushik Nanjibhai Solanki	Jignesh	Visiha Haribhari
Farm Area owned	Between 1 to 5 Acres	Less than 1 Acre	1 to 5 Acres	1 to 5 Acres	Less than 1 Acres
Species grown with No. of cycles	Fish, with 3 or more	Seaweed, with 3 or more	Fish, 1 cycle per year	Fish, 1 cycle per Year	Fish, with more than 3 cycle
Farm Production per year	Less than 2000 Kg	5000 Kg to 10,000 Kg	2000 to 5000 Kg	2000 to 5000 Kg	Between 2000-3000 Kg
Minimum Support Price for selling	No	No	No	No	No
Access to Insurance	Yes, via Private Company	No	Yes, Private Company	Yes, Private company	Yes, Private Company
Access to Internet & Recharge Cost	Yes, more than 1000 Rs.	more than 1000 Rs.	more than 1000 Rs.	Around 2000 Rs.	Yes, more than 1000
Access to Smart Phone (If yes, then use for what)	Communication Only	News & Communication	Communication	Entertainment & Communication	Communication & News
Change in Weather Pattern	Unpredictable weather pattern	Unpredictable weather pattern	Unpredictable weather pattern	Unpredictable weather pattern	Unpredictable weather pattern
Storage	No, Self Manged	No, Self Manged	No	No	No

Importantly, the community did not passively receive the intervention—they offered proactive, grounded suggestions for deployment, including leveraging floating bamboo rafts, using underwater anchoring for sensors, and partnering with the local marine police for safeguarding equipment.

The NDT team responded to this feedback by incorporating several improvements into the APY Tool, such as multilingual interfaces, simplified input fields, and adaptive learning features that continuously refine predictions based on user-reported outcomes. Furthermore, the seaweed cultivation sites in both *Veraval (Gujarat) and Ratnagiri (Maharashtra)* were surveyed in detail by NDT's engineering team to build a stronger regional understanding of ecological variations and cultivation patterns. These data-rich insights are now being fed back into the APY model for contextual customization.

This field engagement reaffirmed NDT's core philosophy: that sustainable and scalable digital transformation in India's fisheries sector must be rooted in grassroots validation, iterative learning, and respect for traditional knowledge systems. It also demonstrated the potential of participatory design in fostering long-term technology adoption, positioning NDT as a trusted enabler of India's transition to a resilient and inclusive blue economy.

2.2 Future work and Scale Up Strategy

Building upon successful field validation and early deployments of the APY Tool, NDT aims to further enhance the platform's technical robustness, reach, and real-world impact. The next phase focuses on leveraging indigenous IoT hardware to scale predictive, AI-powered aquaculture management across India's diverse water systems.

At the core of this effort lies the integration of real-time sensor data (e.g., temperature, pH, salinity, dissolved oxygen, and redox potential) into the APY Tool's backend analytics, enabling more refined decision-making and yield forecasting for small-scale farmers. These low-cost, locally designed sensors will operate reliably across India's extreme aquaculture environments, such as temperature ranges of 5–55°C, salinity gradients from 0 to 40 ppt, and dissolved oxygen variability from 0–18 mg/L. All sensors will be built to resist corrosion and energy fluctuations, with cloud-based architecture ensuring continuous operation even in remote or low-connectivity zones.

The future roadmap includes deploying lightweight floating sensor modules using GPRS and BLE connectivity, allowing farmers to monitor water quality from their smartphones with minimal training. These systems will be accompanied by vernacular-language support, visual dashboards, and a growth-rate curve feature that tracks performance in real time.

The commercial rollout will focus on manufacturing energy-efficient, corrosion-resistant sensor units at scale, with an error margin of less than ±1%, ensuring high fidelity in data-driven predictions. Additionally, built-in UPS and modular SMPS units will support uninterrupted operations, even during power outages.

NDT aims to deepen its policy-level integration by collaborating with government bodies for data-driven resource planning and scheme alignment. These efforts will help formalize digital identities for farmers, enabling easier access to credit, subsidies, and insurance, while reinforcing India's long-term vision for a sustainable and inclusive blue economy.

Workshops and training sessions will be conducted to help farmers interpret AI recommendations, optimize input usage, and reduce production waste. Based on pilot farm feedback, the APY Tool has already demonstrated the potential to increase yield by **25–40%** and reduce input costs by **up to 30%**, validating its economic feasibility for widespread adoption.

3 Appendix

3.1 Supporting Documentation

Provide any documentation you believe supports this Project Proposal. It may be:

[1] AQUACULTURE DATA - Marine Products Export Development Authority - https://mpeda.gov.in/

[2] Seaweeds Cultivation and Utilisation: Prospects in India, October 2018, DOI:10.13140/RG.2.2.24056.70408

[3] The Environmental Impact of Shrimp Aquaculture: Causes, Effects, and Mitigating Alternatives FEDERICO PA´ EZ-OSUNA, DOI: 10.1007/s002670010212

[4] Other Uses of the seaweeds - Food and agriculture organisation Site

[5] Denny - Wave-Energy Dissipation: Seaweeds and Marine Plants Are Ecosystem Engineers, DOI: 10.3390/fluids6040151

[6] The django framework official documentation https://docs.djangoproject.com/en/4.0/

[7] TNAU Agritech portal- https://agritech.tnau.ac.in/fishery/fish_shrimps.html

[8] Wyban, Walsh, Godin, Temperature effects on growth, feeding rate, and feed conversion of the Pacific white shrimp (Penaeus vannamei), 1995/12/01, vol. 138, pp.267-279, 10.1016/0044-8486(95)00032-1

[9] J.A. Wyban, C.S. Lee, V.T. Sato, J.N. Sweeney, W.K. Richards, Effect of stocking density on shrimp growth rates in manurefertilized ponds, Aquaculture, Volume 61, Issue 1, 1987, Pg 23-32, https://doi.org/10.1016/0044-8486(87)90334-6.

[10] Effect of different stocking density on growth, survival of Litopenaeus vannamei (Boone, 1931) in summer and monsoon crop in province of Gujarat States in India, Kotia, Anil, Vadher, K., 2021/05/09, pg.71 99, Vol. 7

[11] Sadek, Nabawi, Effect of water salinity on growth performance, survival, feed utilisation and body chemical composition of the Pacific white shrimp, L.vannamei juveniles https://ejabf.journals.ekb.eg/article_190788_0c44e7f704423a67cf2fd9b19754cc64.pdf

[12] EFFECT OF pH ON PACIFIC WHITE SHRIMP Litopenaeus vannamei GROWTH AND SURVIVAL, Wilson Wasielesky Junior, Heidi Atwood, Ryan Kegl, Jeff Bruce, Al Stokes e Craig Browdy, https://www.aesweb.org/presentations/biofloc/SanAntonio2007/Effect%20of%20pH%20on%20Pacific%20White%20Shrimp%20Litopenaeus%20vannamei%20on%20growth%20and%20survival.pdf

[13] Nonwachai, Purivirojku, Chuchird, Limsuwan's Effect of oxygen levels on growth, survival and Immune response of juvenile pacific white shrimp, Litopenaeus vannamei, https://www.thaiscience.info/journals/Article/KFRB/10892544.pdf

[14] Low Feed Conversion Ratio (FCR) is the Indicator of Efficient Aquaculture, https://doctorshrimp.com/topics_uri/a-low-feed-conversion-ratio-fcr-is-the-indicator-of-efficient-aquaculture/

[15] Soil Quality Analysis of Brackishwater Shrimp Farming in Coastal Areas of Indonesia DOI: 10.5296/jee.v5i2.7043

[16] Changes in shrimp feed quality and effects on growth and survival of Penaeus monodon juveniles DOI: 10.1016/s0044-8486(96)01477-9

[17] Hayashi L, Paula EJ, Chow F, Growth rate and carrageenan analyses in four strains of Kappaphycus alvarezii (Rhodophyta, Gigartinales) farmed in the subtropical waters of Sao Paulo State, Brazil, DOI: ˜ 10.1007/s10811-006-9135-6

[18] Nurul Salma Adenan, Fatimah Md. Yusoff and Mohamed Shariff, 2013. Effect of Salinity and Temperature on the Growth of Diatoms and Green Algae. Journal of Fisheries and Aquatic Science, 8: 397-404 DOI: 10.3923/jfas.2013.397.404

[19] Metsoviti et. Al. (2019) Effect of Light Intensity and Quality on Growth Rate and Composition of Chlorella vulgaris DOI:10.3390/plants9010031

[20] Mujiyanto et al 2020; Suitable water quality parameters for seaweed culture at Muara Gembong coastal area, Bekasi District DOI: 10.1088/1755-1315/521/1/012012

[21] Rodriguez et. al. (2016), Effects of stocking density on the performance of brown shrimp Farfantepenaeus californiensis co-cultured with the green seaweed Ulva clathrata DOI: 10.1111/are.13114

[22] The Effect of Stocking Density on the Performance of the Seaweed Ulva reticulata as a Biofilter in Earthen Pond Channels, Zanzibar, Tanzania DOI: 10.4314/wiojms.v6i1.48227

[23] Rani et. al. Effect of Depth on the Growth and Carrageenan Content of Seaweed Kappaphycus alvarezii Cultivated Using Verticulture Method E3S Web of Conferences 147, 01011 (2020) DOI: 10.1051/e3sconf/202014701011

[24] Knowledge gaps and management recommendations for future paths of sustainable seaweed farming in the Western Indian Ocean DOI: 10.1007/s13280-020-01319-7

[25] Farming and Culture of white legged shrimp , Litopenaeus vannamei, https://agritech.tnau.ac.in/banking/nabard_pdf/Fisheries/5.Culture_of_Vannamei_white_legged_shrimp_15.pdf

[26] TRAINING MANUAL ON RECENT ADVANCES IN FARMING OF PACIFIC WHITE SHRIMP, Penaeus vannamei, CIBA-TM Series 2018- No.14, https://krishi.icar.gov.in/jspui/bitstream/123456789/23385/1/NFDB%20training%20final%20manual.pdf

[27] Recent advancements in the penaeid shrimp, culture, feeds and farming, https://krishi.icar.gov.in/jspui/bitstream/123456789/1149/1/Brochure%206.pdf

[28] LARS HEIN, Toward Improved Environmental and Social Management of Indian Shrimp Farming, DOI: 10.1007/s00267-001-0012-4

[29] Goes HG, Reis RP,Temporal variation of the growth, carrageenan ´ yield and quality of Kappaphycus alvarezii (Rhodophyta, Gigartinales) cultivated at Sepetiba bay, southeastern Brazilian coast, DOI: 10.1007/s10811-011-9665-4

[30] Schmidt EC, Nunes BG, Maraschin M, Bouzon ZL,Effect of ultravioletB radiation on growth, photosynthetic pigments, and cell biology of Kappaphycus alvarezii (Rhodophyta, Gigartinales) macroalgae brown strain, DOI: 10.1007/s11099-010-0022-7

[31] Glenn EP, Doty MS, Water motion affects the growth rates of Kappaphycus alvarezii and related red seaweeds,DOI: 10.1016/0044- 8486(92)90109-X

[32] Luhan MRJ, Sollesta H, Growing the reproductive cells (carpospores) of the seaweed, Kappaphycus striatum, in the laboratory until outplanting in the field and maturation to tetrasporophyte,DOI: 10.1007/s10811-009- 9497-7

[33] Yong, Y.S., Yong, W.T.L. & Anton, A. Analysis of formulae for determination of seaweed growth rate. J Appl Phycol 25, 1831–1834 (2013). DOI: 10.1007/s10811-013-0022-7

[34] Wong et. AL. Effect of different light sources on algal biomass and lipid production in an internal Leds-illuminated photobioreactor, DOI: 10.15436/2381-0750.16.1082.

[35] Zhang et. Al. (2017) Effects of Light-emitting Diodes (LEDs) on the Accumulation of Lipid Content in Microalgae, DOI: 10.12783/dteees/icseep2017/12719

[36] The use of secchi disk - https://www.sciencedirect.com/topics/agriculturaland-biological-sciences/secchi-disk

[37] Estimation of Secchi Depth from Turbidity Data in the Willamette River at Portland, OR (14211720)

[38] MANUAL ON SEAWEED FARMING - Food and agriculture organisation, https://www.fao.org/3/ac416e/ac416e00.htm

[39] Seaweed Farming Training and workshop, https://wsg.washington.edu/community-outreach/kelp-aquaculture/seaweed-farming-training

[40] Top 7 Water Quality Sensors For Water Treatment and monitoring, https://www.renkeer.com/top-7-water-quality-sensors/

[41] Aparna Roy, "Blue Economy in the Indian Ocean: Governance Perspectives for Sustainable Development in the Region", ORF Occasional Paper No. 181, January 2019, Observer Research Foundation

[42] Kumar et. al.(2020) Impact of elevated temperature on the physiological and biochemical responses of Kappaphycus alvarezii (Rhodophyta), DOI: 10.1371/journal.pone.0239097

[43] Lombardi et. Al. Cage polyculture of the Pacific white shrimp Litopenaeus vannamei and the Philippines seaweed Kappaphycus alvarezii, DOI:10.1016/j.aquaculture.2006.04.022

[44] Duy, Nguyen & Nguyen, Tu & Son, Tra & Khanh, Luong. (2015). Automated monitoring and control system for shrimp farms based on embedded system and wireless sensor network. 1-5. 10.1109/ICECCT.2015.7226111.