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Tech-driven aquaculture: Assessing IoT awareness of progressive fish farmers and fisheries professionals in the fisheries sector

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Abstract

The integration of Internet of Things (IoT) in aquaculture offers new possibilities for real-time monitoring and efficient farm management. However, limited adoption and understanding among end-users in India highlights a significant research gap. This study was undertaken with the objective i.e. to assess the awareness, usage, and ownership of IoT devices among progressive fish farmers and fisheries professionals. A total of 120 respondents 60 progressive fish farmers and 60 fisheries professionals were selected for the study. For the objective, respondents were briefed on general and aquaculture-specific IoT devices, followed by interviews with them. Awareness of general IoT devices was 100% among fisheries professionals, while 76.6% of farmers were aware of fitness bands and smart watches, and 73.3% were aware of Alexa. Ownership among professionals was also higher: 60% owned smart watches, 36.6% fit bands, 18.3% Alexa, and 10% Siri. Among farmers, only 12% owned smart watches, 10% owned fit bands, and none owned smart home appliances or voice assistants. For aquaculture-specific IoT applications, 100% of professionals and 75% of farmers were aware of water quality monitoring systems, but none in either group had used or owned any such devices. Respondents rated the IoT suitability of seven aquaculture systems where Biofloc culture received the highest score from both fisheries professionals (0.85) and farmers (0.87), followed by shrimp farming (0.74, 0.77) and recirculatory aquaculture systems (0.63, 0.67). It is clear from the study that while awareness levels are high, actual usage and ownership of IoT particularly in aquaculture are minimal. Both groups consistently identified Biofloc as the most promising system for IoT integration.

Keywords: Internet of things, aquaculture, biofloc culture, fisheries professionals, progressive fish farmers

1. Introduction

The rise of Internet of Things (IoT) technology has revolutionized numerous sectors and has the potential to be adopted in the fisheries and aquaculture also. It is known that IoT enables the interconnection of physical objects with other devices via the internet, facilitating smarter and more efficient operations. Globally, the IoT ecosystem is expanding at an extraordinary pace. As per Statista, the number of connected IoT devices is projected to reach 29 billion by 2030. In the Indian context, the IoT market is anticipated to surge from USD 58.64 billion in 2025 to USD 293.70 billion by 2034, reflecting a robust compound annual growth rate (CAGR) of 19.60% over the forecast period.

In the context of fisheries and aquaculture, the potential of IoT is equally compelling. Globally, IoT market for fisheries and aquaculture sector is expected to grow significantly, reaching 870.02 million by the year 2031, according to InsightAce analytics, 2024 [2].

IoT integration has already gained momentum in India, where aquaculture is a major contributor to food security and livelihoods. IoT-powered water quality monitoring systems enable aquaculture to track parameters such as temperature, pH, dissolved oxygen levels, and ammonia in real time. This integration ensures better management of farm activities, reduce water wastage and losses due to diseases and infections and also effective use of inputs. (Miller *et al*., 2023) [3].

Desk research conducted by Dhenuvakonda and Sharma, 2023 has shown that there are 87 IoTs in fisheries which help in counting of shrimp larvae, estimate biomass, detect appetite, plan feeding schedules, monitor shrimp size/health/water quality parameters/weather conditions, buoys to track temperature, salinity of sea water, smart angling rod, track pH, dissolved oxygen, temperature, ammonia, automatic feed distribution, automatic control of aerators, disease identification etc.

Although IoT is gaining attention in aquaculture and fisheries, its use in India is still not very common. Many studies have shown how IoT can help in aquaculture world wide, there is limited research available regarding the awareness, usage and ownership among the Indian farmers. Moreover, the specific aquaculture systems that an Indian farmer would prefer for IoT development are not much studied.

Despite the rapid growth and potential of IoT technologies in fisheries and aquaculture, there remains a significant gap in understanding their awareness, adoption, and accessibility among stakeholders in India. This disconnect between

technological advancement and grassroots implementation underscores the need for targeted research.

To address this knowledge gap, a study was undertaken to assess the level of IoT awareness, usage, and ownership among progressive fish farmers and fisheries professionals.

Methodology

To collect information related to IoT awareness, usage and ownership, a total of 120 respondents were purposively selected and interviewed for the study. These include**d** 60 progressive fish farmers and 60 fisheries professionals**.** According to Barman and Phukan, 2016 [4] the progressive fish farmers are described as those who are "fit and able to move their farming business to the future". A Progressive farmer actively seeks to improve the farming practices by adopting innovative methods and modern technologies. Fisheries professionals, on the other hand are the individuals possessing specialized education and training in fisheries science, contributing to various sectors such as government fisheries departments, research institutions, academia, and the private sector (Kumar *et al*., 2018) [5].

The progressive fish farmers were identified and interviewed during the Farmers Conclave organized by ICAR-CIBA, Chennai**,** in collaboration with the Society of Coastal Aquaculture and Fisheries (SCAFi) and Navsari Agricultural University (NAU), Gujarat**,** held on February 19–20, 2020**.** This national-level event was attended by approximately 900 brackishwater aquaculture farmers from all coastal states of India, along with participants from select inland states such as Haryana, Punjab, and Rajasthan. From this group, 60 farmers who showed interest in new technologies and improving their farming practices were selected for the study.

The fisheries professionals group consisted of two sub-groups. The first group included 30 participants who attended the Centre of Advanced Faculty Training (CAFT) Programme on Enhancement of Aquaculture and Water Productivity through Engineering Interventions in Biofloc Technology, Aquaponics, and RAS, conducted at ICAR-CIFE, Mumbai**,** from January 16 to February 5, 2020**.** This group represented a cross-section of domain experts including Assistant Professors from fisheries colleges, scientists from research institutions, and subject matter specialists from Krishi Vigyan Kendras (KVKs)**.** The second group comprised 30 postgraduate and doctoral research scholars from ICAR-CIFE, representing various disciplines within fisheries science.

An interview schedule was designed to collect information on farmers and fisheries professionals' profile like age, education, experience. Prior to the interview, the respondents were provided with a write-up on IoT technology which had a brief overview of what is IoT technology, importance of IoT, its applications in our daily life, and applications in fisheries and aquaculture. After briefing the farmers about IoT, questions were asked on: Awareness, Usage and Ownership of general IoT devices, Awareness, Usage and Ownership of IoT in Fisheries and Aquaculture

To collect information about Awareness, Usage and Ownership of general IoT devices a list of commonly used IoT devices was provided which are categorized into three groups: Voice Assistants, Smart Home Devices, and Health Monitoring Devices. The Voice Assistants included Google's Alexa, Apple's Siri, and Microsoft's Cortana. The Smart Home Devices category comprised smart door locks, smart lights, smart ACs, and smart smoke detectors. The Health Monitoring Devices included fit bands and smart watches.

Respondents were asked to answer yes or no questions about their awareness and ownership of general IoT devices. They were also asked to rate their usage on a three point Likert scale: Never, Often and Very often.

Similarly, a list of IoT applications in fisheries and aquaculture was developed based on desk research by Dhenuvakonda and Sharma (2023). Respondents were asked Yes or No to questions for awareness and ownership, and usage was rated for Very Often, Often and Never.

The list included water quality and monitoring system and smart feeding systems for fish farms and shrimp farms, IoT for Biofloc culture, aquaponics, ornamental fisheries, cage culture, recirculatory aquaculture system, angling with smart fishing rods, smart buoy technology, under water remotely operated vehicles, IoT in supply chain, drones for ocean water sample collection and surveillance, fishing vessel tracking. Percentage analysis was done to determine the awareness, usage and ownership.

Finally, a list of aquaculture systems with IoT potential was given to the respondents to rate these systems based on their perceived prospects for IoT development using a five-point Likert scale: Very High Prospect (5), High Prospect(4), Moderate Prospect (3), Low Prospect (2), and Very low Prospect (1). The list included fish farms, shrimp farms, Biofloc culture, recirculatory aquaculture system, cage culture, aquaponics and ornamental fisheries.

The scores obtained on a five point scale were normalized to 0-1 scale. Normalizing scores from a 5-point scale ensures that variations across different measures are standardized, making comparisons more meaningful and interpretable. By transforming the scores to a range between 0 and 1, normalization eliminates scale biases and allows for direct comparisons across different datasets or contexts. To obtain the normalised scores below formula is used.

$$X' = \frac{X - Xmin}{Xmax - Xmin}$$

Where, X' = Normalized value
X= Original value
Xmin= Minimum value in the dataset
Xmax= Maximum value in the dataset

This study was conducted in the year 2020. Since then, the fields of Internet of Things (IoT) and Artificial Intelligence (AI) have undergone rapid advancements, including the emergence of new technologies, tools, and applications relevant to fisheries and aquaculture. As a result, the findings may not fully reflect the current state of awareness or adoption among fish farmers and fisheries professionals. This temporal gap represents a limitation of the study and highlights the need for ongoing research to capture evolving trends and technological integration in the sector.

Results and Discussion

Profile of Fisheries professionals and Progressive fish farmers

The profile of the fisheries professionals and progressive fish farmers like age, education and experience are collected. The results are given in table 1 and 2 respectively.

Age: Among fisheries professionals, the majority (58.33%) fall within the young age group (18-35 years), while the remaining 41.66% belong to the middle age group (36-50 years). Most progressive fish farmers (85%) are in the middle-aged group (36-50 years), while 6.6% are young (18-35 years), and 8.33% are older than 50 years.

Education: Fisheries professionals have higher education levels, with 33.33% being postgraduate students, 25% being PhD scholars, and 41.66% holding a PhD degree. Among the farmers, 25% have secondary education, 33.33% have completed higher secondary education, and 41.66% hold a graduation degree.

Experience: Experience levels among Fisheries professionals show that all professionals (100%) have less than 15 years of experience, with none having medium (16-30) or high (>30) years of experience. Among farmers, majority (71.6%) have medium experience (16-30 years). About 21.6% have less than 15 years of experience, and 6.6% has over 30 years of experience.

Table 1: Profile of fisheries professionals

Variable	Criteria	Frequency	Percentage
Age	Young Age (18-35)	35	58.33%
	Middle Age (36-50)	25	41.66%
	Old Age (>50)	0	0%
Education	PG Students	20	33.33%
	PhD Scholars	15	25%
	PhD	25	41.66%
Experience	Less (0-15)	60	100%
	Medium (16-30)	0	0%
	High (>30)	0	0%

Table 2: Profile of progressive fish farmers

Variable	Criteria	Frequency	Percentage
Age	Young Age (18-35)	4	6.6%
	Middle Age (36-50)	51	85%
	Old Age (>50)	5	8.33%
Education	Secondary	15	25%
	Higher secondary	20	33.33%
	Graduation	25	41.66%
Experience	Less (0-15)	13	21.6%
	Medium (16-30)	43	71.6%
	High (>30)	4	6.6%

Awareness of IoT devices

The results indicated that all fisheries professionals were aware of the listed IoT devices. Among the farmers, 63.3% were aware of Siri, 73.3% were aware of Alexa, and 76.6% were aware of both fit bands and smart watches. Furthermore, 55% of the farmers were aware of smart home devices such as smart door locks, smart ACs, and smart smoke detectors. Figure 1 shows the graphical representation of awareness of IoT devices among fisheries professionals and progressive fish farmers.

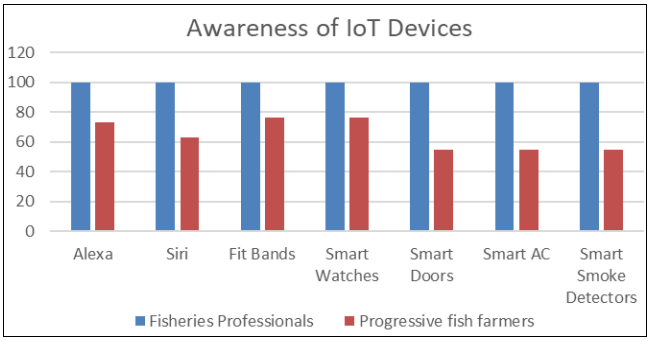

Fig 1: Awareness of IoT devices among fisheries professionals & progressive fish farmers

Ownership of IoT devices

Among the fisheries professionals, 18.3% had access to Alexa, 10% have access to Siri, 60% owned smart watches, and 36.6% owned fit bands. None of the fisheries professionals owned smart home appliances or the Cortana voice assistant. In contrast, among the farmers, 12% owned smart watches, 10% owned fit bands, and none owned voice assistants or smart home appliances. Figure 2 presents the graphical representation of ownership of IoT devices among fisheries professionals and progressive fish farmers.

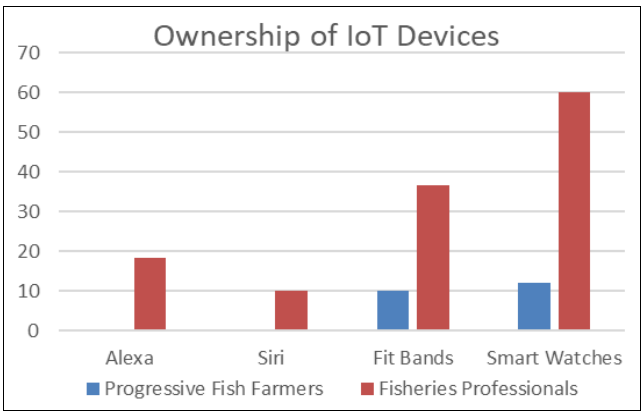

Fig 2: Ownership of IoT devices among fisheries professionals & progressive fish farmers

Usage of IoT devices

To determine the usage frequency of the owned IoT devices, respondents were asked to categorize their usage as "never," "often," or "very often." Among fisheries professionals, 65% reported using their IoT devices very often, while 35% used them often (Figure 3). The IoT devices most frequently used by fisheries professionals were smart watches and fit bands**,** which were categorized as being used very often**.** On the other hand, Alexa and Siri were often used by the fisheries professionals. Among farmers, 55% used their IoT devices very often, 35% used them often, and 10% never used the devices (Figure 4). Smart watches were the devices most commonly used very often by farmers, while fit bands were used often**.**

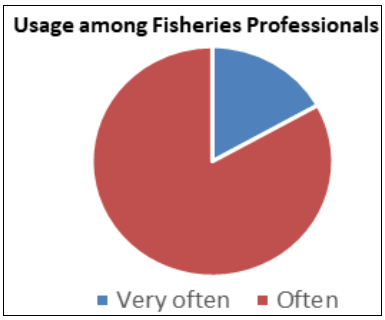

Fig 3: Usage of IoT Devices among fisheries professionals

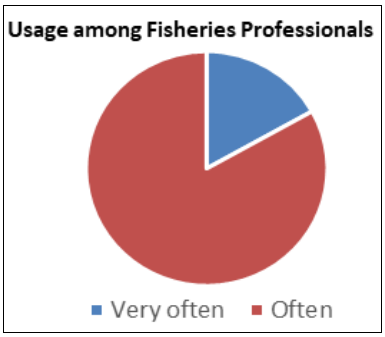

Fig 4: Usage of IoT Devices among farmers

Awareness, ownership and usage of IoT in Fisheries and Aquaculture

Among fisheries professionals, there was 100% awareness of both water quality monitoring systems and smart feeding systems, 41.6% for smart fishing rods, underwater ROV systems and recirculatory aquaculture systems, 33.3% for smart buoys, and none of them are aware of IoT systems for biofloc, aquaponics, cage culture and ornamental fisheries. Among fish farmers 75% of them are aware of water quality monitoring systems, 66.66% smart feeding systems, and none of them are aware of smart fishing rods, smart buoys, underwater ROV systems and IoT for biofloc, aquaponics, ornamental fisheries, cage culture and recirculatory aquaculture system. None among the fisheries professionals and fish farmers own or used any IoT device for aquaculture.

Even though they do not own or use IoT devices, their awareness showed that they understand how these technologies can help in improving efficiency, reduce labour, and increase production. The fact that they have not adopted IoT does not mean they are not interested. Instead, it points to challenges like high costs, lack of technical support, and poor infrastructure. Also, farmers, even without using IoT, wanted a solution for the problems they face, such as water quality issues, fish diseases, and feeding difficulties. Their knowledge about these challenges is valuable in designing IoT solutions that can truly help improve aquaculture.

Prospective aquaculture system for IoT prototype development

Among fisheries professionals, Biofloc culture received the highest rating (0.85), followed by shrimp farms (0.74), recirculatory aquaculture systems (RAS) (0.63), and fish farms (0.56). Aquaponics (0.57) and ornamental fish culture (0.44) were rated lower, while cage culture (0.29) had the lowest rating.

Similarly, farmers also ranked Biofloc culture as the most prospective system for IoT development (0.87), followed by shrimp farms (0.77), recirculatory aquaculture systems (0.67), and fish farms (0.59). Aquaponics (0.53) and ornamental fish culture (0.38) had lower ratings, while cage culture (0.22) was rated the least suitable.

Conclusion

The integration of IoT technology holds significant promise for advancing the fisheries and aquaculture sector in India. Both fisheries professionals and fish farmers had high awareness of general IoT devices, but ownership and usage were limited. With respect to awareness, ownership and usage of IoT in fisheries and aquaculture, awareness was highest for water quality monitoring and smart feeding systems, but none of the respondents owned or used IoT devices for their farms, highlighting a gap between awareness and adoption. Both groups ranked Biofloc culture as the most prospective system for IoT development followed by Shrimp Farming and Recirculatory Aquaculture Systems (RAS). Mann-Whitney U test results showed no significant difference in perceptions between the two groups, and Cohen's Kappa test confirmed agreement in rankings.

Despite growing awareness, high costs, lack of support, and infrastructure challenges hinder adoption. Addressing these barriers is crucial to advancing IoT in aquaculture and enhancing efficiency, productivity, and sustainability. This suggests that there is a need for targeted interventions to bridge the gap between awareness and adoption. The potential interventions include capacity building and training to enhance knowledge and skills related to IoT applications in fisheries and aquaculture, providing financial incentives, subsidies to encourage the adoption of IoT technologies, investing in research and development to develop cost-effective and user friendly IoT solutions.

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