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Small-holder Fish Farming in the Upper Kuttanad and Brackish Water Villages of Alappuzha District, Kerala, India

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Authors' contributions

This work was carried out in collaboration between all authors. Author LPC Designed the study and wrote the protocol. Author AA Performed the statistical analysis and wrote the first draft. Authors LPC and AA done the literature searches and analysis. Both authors read and approved the final manuscript.

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ABSTRACT

In Kerala, smallholder aquaculture emerges as an alluring and significant part of rural lives, improving livelihoods and ensuring a sustainable supply of inland fish. One hundred and four smallholder fish farms were surveyed from the upper Kuttanad and brackish water villages of Alappuzha, the state's leading district for inland fish production. Personal interviews and questionnaires were employed to get primary data on species farmed, culture method, feed, and the challenges smallholder farmers faced. The most common fish species cultured in smallholder fish farms is *Oreochromis niloticus* (GIFT) (34%), followed by *Etroplus suratensis* (31%), *Pangasius pangasius* (15%), *Anabas testudineus* (6%), Channa striata (6%), *Labeo rohita* (4%), and *Heteropneustes fossilis* (4%). In the brackish water villages, 60% of the fish cultured are *Etroplus suratensis*. Eighty-one per cent of the farmers used ponds, 11% used biofloc, and 8% used cages. Sixty-six percent of farmers used commercially manufactured pellet feed, 21% poultry waste, 12%

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used food waste, and 1% live Black soldier flies. Fish cultured using the bio floc method are the most affected by the fungal disease, gill rot. *Anabas testudineus* cultured at high stocking density in bio floc showed tail-biting behaviour followed by bacterial infection. Fifty-one percent of farmers reported a lack of appropriate technical and financial aid from the government, including the withdrawal of subsidies for feed purchases. Even though the 2018 flood seriously affected the fish farms, only 8% of farmers reported the flood as a problem affecting their farms. The major challenges brackish water farmers faced were the intrusion of saline water from the nearby lake and the poaching of juvenile and mature fish from natural ponds. Apart from the monetary assistance provided by the government for starting farms under the "Jankeeya Matsya Krishi" Project, smallholder farmers should need additional help with insurance and subsidies to promote sustainable aquaculture.

Keywords: Smallholder aquaculture; upper kuttanad; brackish waters; Oreochromis niloticus; Etroplus suratensis; biofloc; pellet feed; gill rot.

1. INTRODUCTION

Fish is considered the most promising food for human consumption, and its high nutrient profile is very relevant at present, as it helps to develop immunity against emerging diseases. The demand for fish has been growing due to the significant changes in many societies' diet patterns [1]. This, coupled with the dwindling availability of wild fish catch due to climate change and associated issues, has created a mismatch between the demand for fish products and their supply, driving the necessity of finding other avenues of fish production [2]. Enhancing aquaculture production can bridge this gap, for which a shift from extensive to intensive farming is needed, along with the expansion of aquaculture areas and diversification of culture species [3]. Rural household fish farming has been recognized as a promising avenue to augment the supply of nutrient-based and cost -effective fish products [4]. For some households whose principal source of income is highly volatile, the earnings from the fish farming activity may help in smoothing such income shocks emanating from varied reasons, including job loss and climate change [5]. Among the states of India, Kerala is the largest fish-consuming state, with more than 85% of the population eating fish at an average per capita fish consumption of 27–30 kg, four times the national average [6]. Although a considerable quantity of fish is produced in Kerala, about 2 lakh tonnes of fish are brought annually from outside the state to meet the domestic requirement. [7].

Kerala, which occupies 7% of the water bodies in the country, has the scope to improve the utilization of its resources in inland fishing. Through creative projects like "Janakeeya Matsya Krishi," the Kerala government encourages smallholder fish farmers in the fishing villages to start advancing sustainable techniques for the growth of aquaculture. Aquaculture methods and technology have advanced quickly from basic facilities to highly technological systems focusing on the target species' growth and survival rates [8]. In Kerala, Alappuzha, Thrissur, and Palakkad are the leading districts for inland fish production, occupying the first, second, and third positions, respectively. Alappuzha district has the highest number of inland fishermen and ranks second in inland fishing villages, falling in the deltaic zone of the Kuttanad wetland ecosystem [9].

The study aimed to gather data on smallholder fish farming, focusing on a subset of these households from the upper Kuttanad and brackish water villages of Alappuzha district. The study's goals included observing different culture methods, species, types of feed, and the challenges and problems the smallholder farmers faced. The study also examined the main issues surrounding smallholder fish farming and recommended developing the sector.

2. MATERIALS AND METHODS

2.1 Study Area

Smallholder fish farms from Upper Kuttanad and Brackish water villages of the Alappuzha district (Table 1).

Table 1. GPS Co-ordinates of the fish farms in upper Kuttanad and brackish water villages of the Alappuzha district

Upper Kuttanad	Latitude	Longitude
Thalavady	9.3700°N	76.4977°E
Muttar	9.4009°N	76.4809°E
Edathua	9.3661°N	76.4722°E
Brackish water		
Chingoli	9.2503°N	76.4520°E
Arattupuzha	9.1126°N	76.2823°E
Muthukulam	9.2168°N	76.4592°E

The study was conducted from May 2022 to June 2023, following the methodology of Chirindza and Thorarensen [10]. Hundred and four smallholder fish farms were randomly selected for the survey from Thalavady, Muttar, and Edathua villages of upper Kuttanad, and Chingoli, Arattupuzha, and Muthukulam brackish water villages of Alappuzha district Table 1. Personal interviews and questionnaires Appendix 1. were employed in this study to get primary data on fish farming, such as species farmed, type of farming, feed, and the challenges and problems the smallholder farmers faced. The secondary data was collected from the coordinators and promoters of Malsyabhavan, Department of Fisheries, Alappuzha, through consultation and telephone communication. An analysis of the data was conducted using Microsoft Excel. The result was illustrated using descriptive statistics.

3. RESULTS AND DISCUSSION

The most common fish species cultured in smallholder fish farms is *Oreochromis niloticus* (GIFT) (34%), followed by *Etroplus suratensis* (31%), *Pangasius pangasius* (15%), *Anabas testudineus* (6%), *Channa striata* (6%), *Labeo rohita* (4%) and *Heteropneustes fossilis* (4%) (Fig.1). These findings are consistent with report Food and Agricultural Organization of United Nations [11]. The mono-sex culture of GIFT tilapia is advantageous in smallholder fish farms because of its faster growth rate and more extensive and uniform size. As tilapia represents a lower level in the food chain, its culture will be economical and eco-friendly [12]. In the brackish water villages of the Alappuzha district, 60% of fish species cultured are *Etroplus suratensis*. The state fish of Kerala has a strong market demand and price, making it a great candidate species for aquaculture expansion [13]. This species is suitable for culture in confined, brackish waters [14], as observed in the successful cage culture in backwater farms of the Alappuzha coast. *Channa striata*, *Anabas testudineus*, *Pangasius pangasius*, *Labeo rohita*, and *Heteropneustes fossilis* are cultured exclusively in the upper Kuttanad and *Etroplus suratensis* in the brackish water farms. Besides fish culture, mud crab (*Scylla serrata)* and white-leg shrimp (*Litopenaeus vannamei)* were also successfully cultured in the brackish water farms (Fig. 7).

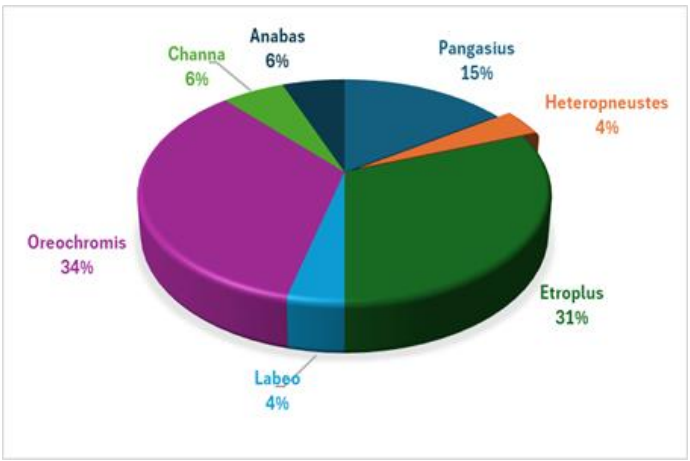

Fig. 1. Fish species farmed

Pangasius pangasius was the second preferred species in upper Kuttanadu due to its high growth rate and disease resistance, also reported by Sahoo and Ferosekhan [15]. The tubular air sacs of the freshwater air-breathing fish *Heteropneustes fossilis* enable it to survive in low-oxygen conditions. It is resilient to both low-quality water and high carbon dioxide levels. Being omnivorous, it can survive in a range of environments. In Upper Kuttanad villages, *Heteropneustes fossilis* is raised at a high stocking density in natural ponds due to its tolerance to overcrowded situations, as reported by Ignatiou et al [3].

Anabas testudineus is cultured in the natural ponds and biofloc systems in Upper Kuttanad farms. The stocking density of this species is one of the crucial aspects for optimizing feed and water quality management in biofloc systems. [16]. The hardy nature of *Anabas testudineus* makes its survival and growth in natural ponds easier, even in oxygen-depleted conditions, with the help of labyrinthine organs [3]. *Labeo rohita* is the carp variety with a high growth rate [3]. cultured in natural ponds in the Upper Kuttanad villages.

The fast growth rate, hardy nature, high consumer preference, lucrative market value, and ability to withstand adverse conditions make *Channa striata* another preferable culture species [3] in the ponds of Upper Kuttanad. The farmers are also trying to diversify aquaculture in the brackish water regions to highly valued shrimp and crab culture (Fig.7) by introducing new genetically modified species [17].

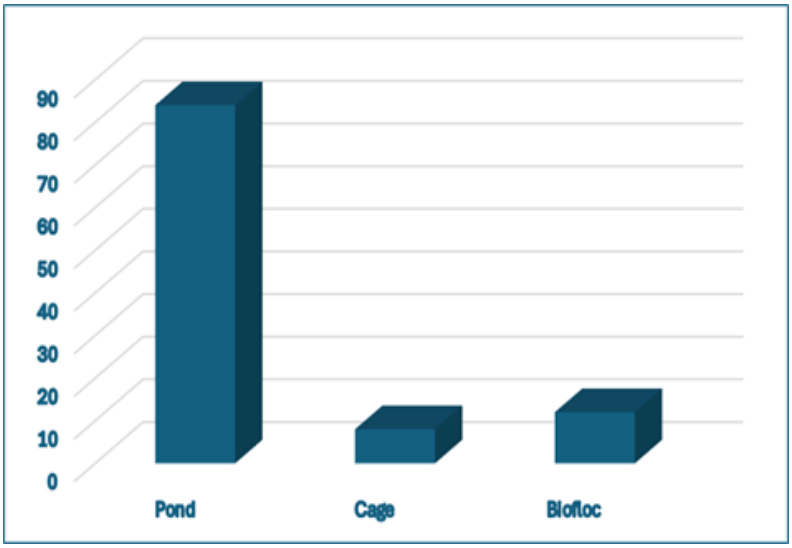

Fig. 2. Culture methods

Fig. 3a. Pond culture of *Heteropneustes fossilis* in Upper Kuttanad

Fig. 3b. Pond culture of *Oreochromis niloticus* in Upper Kuttanad

Fig. 3c. Pond culture of *Etroplus suratensis* in Brackish waters

Fig. 4. Biofloc Method of *Anabas testudineus*

Fig. 5. Monitoring of water quality parameters in biofloc

Fig. 6. Cage culture of *Oreochromis niloticus*

Fig. 7. Concrete tanks for culturing crab and shrimps

Eighty-one percent of the farmers use natural ponds for farming different fish species, followed by 11% biofloc and 8% cages (Fig.2,3 a,b,c). Innovative fish culture methods such as the biofloc culture were practised, especially for *Oreochromis niloticus* and *Anabas testudineus* (Fig.4). Environmental quality conditions significantly impact aquaculture operations, particularly water and soil characteristics [18]. Smallholder farmers only cared a little about the water or soil quality parameters, except pH. Farmers that use natural ponds for culture try to keep the pH between 6.5 and 7.5 by adding calcium carbonate when preparing the pond. In biofloc culture, only very few farmers periodically check the dissolved oxygen, pH, and salinity using electronic monitoring devices (Fig.5). It is interesting to note that, despite the advent of several contemporary aqua farming techniques, such as Biofloc fish farming, people still like pond fish farming because it is a natural and environmentally beneficial way [19]. The cage culture of *Oreochromis niloticus* was also practised in the Pamba River of upper Kuttanad villages. In addition to pond culture, cages made of galvanised iron pipes placed in a brackish water area, the Kayamkulam Kayal, were used to culture *Etroplus suratensis* (Fig.6).

Sixty-six percent of farmers used commercially manufactured pellet feed, 21% poultry waste, 12% used food waste collected from home and catering services, and 1% used live feed, Black soldier flies (Fig.8). Pellet feed is used as floating or buoyant feed, as most fish species can be trained to accept floating pellets. Feeding a floating (extruded) feed allows the farmer to see the fish's feeding intensity up close and modify feeding rates accordingly [20]. Black soldier fly (BSF) larval meal (Fig. 9 a&b) can be used as a substitute source of protein to lower production costs in the aquaculture sector without sacrificing the quality of the fish [21]. Determining whether feeding rates are too low or too high is essential in maximizing fish growth and feed use efficiency [19].

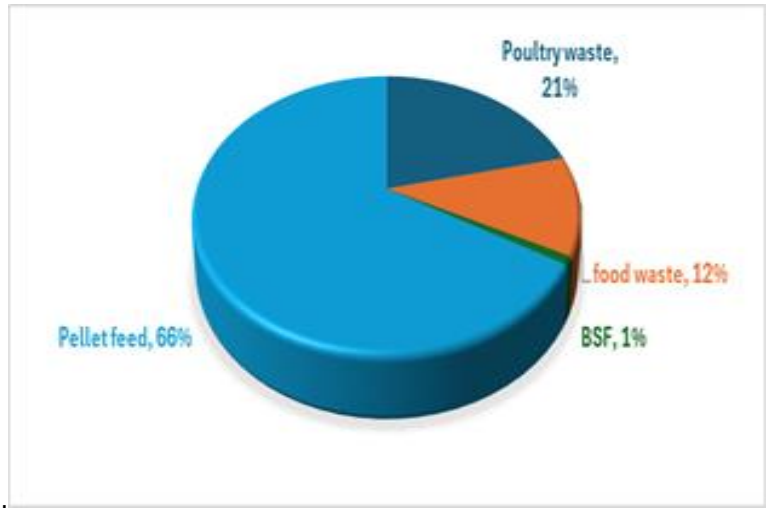

Fig. 8. Feed type

Fig. 9a. Live feed (Black Soldier Fly) culture

Fig. 9b. Cultured black soldier fly

The major issues affecting fish farms have been identified (Fig.10). Although the 2018 catastrophic flash flood has significantly impacted fish farming, only 8% of farms in the study had flood damage following that year. 12% of fish farms faced serious problems due to bacterial and fungal diseases. Fishes cultured using the biofloc method are the most affected by the fungal disease, gill rot. Fish are more vulnerable to fungal infections and fungal-like diseases; the main reason for the difficulty in detecting infection is a lack of outward symptoms and indicators [22].

Anabas testudineus cultured at high stocking density in biofloc showed tail-biting behaviour followed by bacterial infection. The fish industry suffers greatly from many opportunistic bacterial infections and parasites, resulting in increased chemical control and prevention costs, decreased growth, and high morbidity and mortality rates [23]. The fish cultured in natural ponds were more resistant to diseases. Brackish water species are less prone to diseases.

In smallholder fish farms, aquaculture development is impeded by inadequate technical and financial support [24,25]. Fifty-one per cent of these smallholder farmers reported a lack of technical support and financial aid from the government, including the withdrawal of subsidies for feed purchases. Another major challenge the farmers faced was the intrusion of saline water from the nearby lake and natural water bodies. Poaching of juvenile and mature fish from natural ponds greatly reduced their yield.

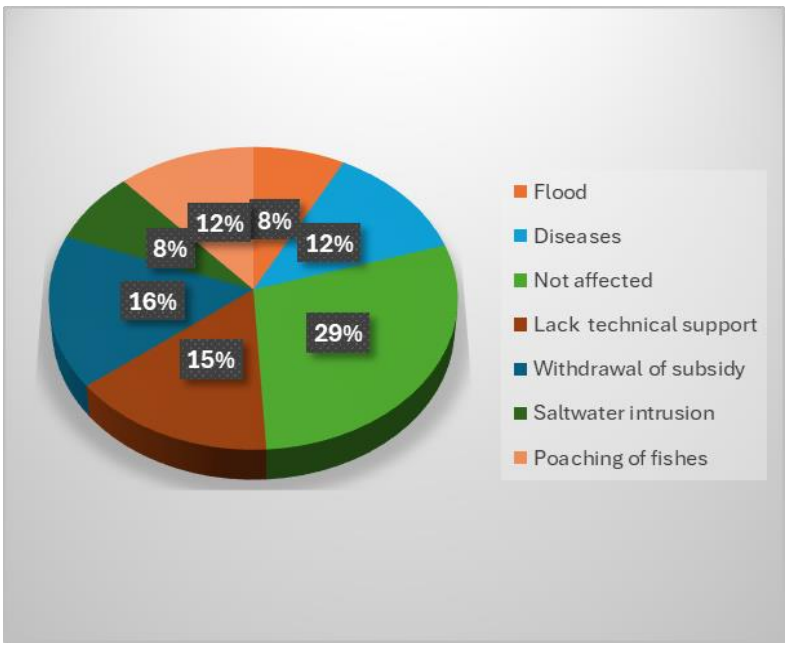

Fig. 10. Problems faced by the smallholder farmers

Alappuzha District, situated on the Kerala coast, boasts a significant portion of the Kuttanad wetland and holds promise for freshwater and brackish water aquaculture. However, the district grapples with challenges such as recurrent floods and saline intrusion. The primary factor influencing aquaculture's sustainability and success is land suitability [26]. The key to overcoming these hurdles and optimizing production and sustainability lies in conducting a land suitability analysis using a Geographical Information System (GIS) [27,28]. This analysis will determine the suitability of land for brackish water aquaculture and its limiting variables, providing a valuable tool for decision-makers as they formulate the 'Regional Spatial Plan' for the district, following the successful model implemented in Indonesia's District West Halmahera [29].

4. CONCLUSION

Land appropriateness is a crucial factor influencing the profitability of large-scale and intensive aquaculture operations. In this context, smallholder farmers can benefit from the technical support provided by the aquaculture promoters. This support includes a land suitability analysis before farm setup, enabling farmers to categorize their farms as highly suitable, moderately suitable, marginally suitable, or non-appropriate. As the fish farms are in flood-prone areas of Kerala state, experts in the field have to arrange monthly training sessions to address the challenges farmers face during unpredictable climatic changes. It is not feasible for smallholder farmers to routinely use electronic devices to check soil and water quality parameters. The government's aquaculture promoters should handle this. Using molecular methods, aquaculture promoters can also assist farmers in identifying disease-causing organisms and providing precise treatment recommendations.

Updated information can also be provided at the field level regarding new farming techniques like biofloc tanks and cages, the introduction of genetically modified varieties, feed, and proper farm management during disease outbreaks. A genetically improved, disease-resistant variety of *Labeo rohita* (Jayanti rohu) with a high survival rate can be introduced in smallholder upper Kuttanad fish farms. Guidance can be given for the effective marketing and distribution of their products.

The initial large subsidies provided by the government seem to draw many people into starting their businesses, including fish farming, with the hope of promoting these kinds of endeavours. Smallholder farmers are at high economic risk during unpredictable climatic conditions and disease outbreaks due to the lack of insurance coverage. In addition to the subsidies given by the Government through the 'Jankeeya Matsya Krishi' Project, more financial aid, including insurance coverage and support, should be given to smallholder farmers to encourage indigenous sustainable aquaculture practices and to improve their livelihood.

Through capture and culture fisheries, Kerala's aquatic habitats contribute significantly to social and economic growth, food and nutritional security, and both. Intensifying capture fisheries would negatively impact the sustainability of natural fishery resources, which is not ecologically feasible. The culture fishery is regarded by many nations worldwide as the major source of food supply for this century and is one of their top priorities. Kerala state, which has initiated aquaculture operations, is preparing for a dramatic increase in aquaculture output. Smallholder fish farms in rural areas must be prioritised as part of the state’s venture to achieve the goal.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX 1

A SURVEY OF SMALL-SCALE RURAL FISH FARMING

I. PERSONAL DETAILS

- Name of the farmer:
- Sex:
- Age:
- Educational qualification:
- Experience:
- Main occupation:
- Family size:

II. LOCATION

- District:
- Village:
- Panchayat:

III. DESCRIPTION OF FISH FARMS

- Fish culture in

  Pond Cage Bio flocs Others:

- Farmed species.

  Tilapia Etroplus Others

- Feeding

  Rice Vegetable waste Poultry waste

  Pellet feed Others:

- Maintenance status

  Good poor

IV. ENVIRONMENTAL ASPECTS

- Is water entering the pond treated?

  Yes No

- pH of water and soil:

  Maintained Not

V. ECONOMY AND PROFIT

- Fish catch per harvest:
- Is it profitable?

Yes No Just breakeven.

- Financial assistance from the Fisheries Department

  Yes No

  If yes, which scheme:

- Technical support:

  Yes No

- Insurance coverage:

  Yes No

VI. CHALLENGES AND PROBLEMS

- Diseases found:
- Effect of flood:
- Saltwater intrusion:
- Other problems:

Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.mbimph.com/review-history/3374