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Skill enhancement of frontline fisheries employees as a driver of sustainable aquaculture development

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Abstract

Frontline fisheries workers are becoming more and more important to the success of aquaculture as a whole due to the critical roles they play in transferring technology, advising farmers, and implementing best management practices. Sustainable aquaculture development is the focus of this study, which looks at how training frontline fisheries workers might help. Using a systematic and verified questionnaire, 110 frontline fisheries employees provided primary data for a descriptive and analytical research study. The study examined various aspects of skill development, such as technical fish farming, digital competencies, managerial abilities, communication and extension, and environmental management. Research showed that those working on the front lines of the fishing industry had a decent to excellent set of abilities, with an emphasis on technical and environmental knowledge. Improving one's general skill set was positively correlated with the results of sustainable aquaculture development.

According to the research, sustainable aquaculture development is greatly aided by programs that systematically improve aquaculturists' skills. Improving aquaculture productivity, resource efficiency, and long-term ecological balance can be achieved through strengthening training programs, particularly in digital technologies and environmental sustainability. The results provide important information for fisheries departments, extension agencies, and legislators who are trying to promote sustainable aquaculture by developing human resources.

Keywords: Skill enhancement, frontline fisheries employees, sustainable aquaculture, capacity building, fish farming

1. Introduction

The fisheries sector has made sustainable aquaculture development a top priority due to rising fish consumption, declining natural resource availability, environmental deterioration, and climate-related problems. When it comes to putting scientific discoveries, best management practices, and policies into reality at the local level, frontline fisheries staff are indispensable. Their performance is crucial in determining the level of adoption of sustainable aquaculture practices and the achievement of institutional goals, as they constitute the main link between fisheries institutions and aquaculture farmers. Given its direct impact on production, environmental stewardship, and livelihood outcomes, skill training of frontline fisheries staff has emerged as a critical driver of sustainable aquaculture development in this setting.

Technical fish farming skills, understanding of sustainability and the environment, communication and extension abilities, administrative and planning abilities, and digital and ICT-based skills are all part of skill enhancement. The key to increasing output while decreasing losses is having technically competent frontline workers who can advise farmers on better seed quality, feed management, disease control, and water quality maintenance. Employees with environmental sustainability skills also encourage sustainable farming practices, appropriate resource management, and regulatory compliance, all of which lessen aquaculture's impact on the environment. Even the most well-planned development plans fall flat if the people involved lack the necessary abilities.

Effective knowledge transfer and behavior modification among aquaculture producers requires not just technical and environmental competencies, but also strong communication and extension skills. The ability to connect with varied farming groups, recognize local restrictions, and adapt advisory services appropriately are all skills that frontline fisheries

staff should possess. Employees and farmers are more likely to trust one another, innovations are adopted more quickly, and joint action for sustainable resource management is encouraged when skills in interpersonal communication and participatory extension approaches are enhanced. Similarly, frontline workers with administrative and planning abilities may better oversee aquaculture systems as a whole by implementing development schemes, monitoring progress, and coordinating with various stakeholders.

The need for skill enhancement is further highlighted by the increasing use of digital technology in fisheries management. Workers in the field of fisheries who are proficient in digital and ICT-based skills are better able to make use of resources such as online training platforms, data management systems, mobile advisory services, and decision-support tools. These abilities improve the timeliness, accuracy, and reach of extension services, especially in places with limited resources. Decisions, transparency, and resilience in aquaculture growth can be enhanced by combining digital capabilities with traditional technical expertise.

By bolstering human capital in the fisheries sector, training frontline workers' skills is a key driver of long-term aquaculture development. By improving their abilities, frontline workers can better connect theory with reality, advocate for more environmentally friendly production methods, and boost the financial and social standing of aquaculture producers. So, to achieve sustainability, productivity, and inclusivity in aquaculture in the long run, it is vital to engage in the capacity-building and CPD of frontline fisheries staff.

2. Review of Literature

Tosun, Deniz *et al.*, (2025) ^[13]. Aquaculture in Turkey's İzmir Province's Karaburun-Ildır Bay Special Environmental Protection Area (SEPA) is the subject of this socio-economic and ecological study. The SEPA, which includes a wide variety of marine and terrestrial ecosystems, is vital for the preservation of biodiversity and for economic pursuits, especially aquaculture. Important players in the aquaculture business in the area, such as fish farms, processing facilities, and feed providers, are the subject of the study's purposive sampling. Structured interviews were used to gather survey data that assessed economic impacts, community development, job creation, and job security. In 2021, the Karaburun-SEPA contributed 14.44% of Turkey's total marine fish production and 33.23% of İzmir's marine fish output, mainly through its aquaculture operations with European sea bass (*Dicentrarchus labrax*), gilthead seabream (*Sparus aurata*), meagre (*Argyrosomus regius*), and Atlantic bluefin tuna (*Thunnus thynnus*). This sector contributed 37% to İzmir's GDP and 10% to Türkiye's marine aquaculture sector in 2021, with an estimated economic value of 174.17 million USD. Including family members, an estimated 1,864 persons in the area profit from the region's fish farms, which employ 486 people according to the employment statistics. Floating cages and feed manufacturing facilities are examples of the substantial infrastructure investments that highlight the capital intensity of the sector. The results show how important the area is to Türkiye's aquaculture sector and how important it is to find a way to grow economically while protecting the environment. In order to guarantee ecological and economic stability in the long run, the study highlights the significance

of incorporating sustainability into aquaculture development and gives useful insights into the socio-economic benefits of aquaculture in a protected region.

Bunting, Stuart. (2024) ^[2]. This article provides a critical analysis of a toolbox of ideas that could aid in the development of sustainable aquaculture by drawing on real-world instances and written reports. To help promote sustainable and healthful meals on a worldwide scale, we present the ideas of aquatic food systems and systems thinking. Methods for evaluating stakeholders, institutions, and markets in order to promote fair and suitable aquaculture development are examined. The article summarizes the main points of a participatory evaluation of desirable qualities, outlines the future of genetic enhancement programs, and discusses some of the problems that might occur from gene editing. A critical study of participatory action planning is conducted in order to enhance shared assessment and decision-making for the management of peri-urban wetland areas in West Bengal, India. Possibilities and limitations are examined while seven tenets of participatory action planning are laid out. This section explains the STEPS method of conducting stakeholder feasibility studies: social, technical, environmental, political, and sustainability. We take a look at the arguments for aquaculture planning based on consensus and evaluate the stakeholder Delphi method for reaching consensus and measuring agreement levels. Social, economic, and environmental ramifications are examined in light of stakeholder Delphi assessment conclusions pertaining to the use of tiny pelagic fish species as feed ingredients in sub-Saharan Africa. We take a look at the potential for improved environmental impact assessments with stakeholders and highlight promising ways to collaborative economic and financial appraisals.

Komlatsky, Grigory. (2024) ^[7]. A comprehensive assessment of the Russian and Krasnodar Territory fishing complex was conducted by extrapolating a wide range of statistical and analytical data. We now know how much of an impact the industry can have in addressing food security. It has been observed that Russians produce a good amount of fish items on their own. The present status and characteristics of the functioning of the fishing sector on a global and Russian scale are ascertained. The United Nations Food and Agriculture Organization's Blue Transformation initiative has revealed a worldwide trend toward more commercial aquaculture production, and it has also identified the conditions necessary for this trend to emerge in Russia. Meanwhile, it seems that Russia's aquaculture development level is out of line with the country's natural capabilities. Research into aquaculture in Russia's southern regions has led to the identification of factors that have contributed to a drop in commercial fish production in the region's freshwater bodies. Pond farms and lake-type farms' potential for reviving and expanding commercial fish farming has been identified. In this document, the Krasnodar Territory's coastal Black Sea coast aquaculture reserves, including mariculture, are detailed. The necessity to update the sector and the practicability of establishing commercial aquaculture in RAS systems with little management are both proven. There have been suggestions to explore ways to speed up the growth of fish feed production and to further increase government support

measures in order to decrease reliance on imports. It is now established that aquaculture is the engine that drives the fishing complex in the modern era. A conducive investment climate, state financial backing, and the formation of public-private partnerships in the execution of pertinent projects are essential for the industry's continued successful development. As the aquaculture business continues to grow, more fish products will be available, more people will eat them, and more people will work and earn money.

Paruđ, Şenol *et al.*, (2024) ^[10]. Examining the fisheries and aquaculture industries in five North African nations—Egypt, Morocco, Algeria, and Tunisia—this research draws attention to the vital significance these industries play in ensuring economic stability and food security in the face of rising regional needs for animal protein. Inadequate international collaboration, a lack of information, and inadequate institutional frameworks make fisheries management a struggle in most of these locations, despite the rich marine ecosystems and large contributions to national economies and jobs. In order to maintain natural fish supplies and increase food production capacities, the article stresses the importance of moving towards sustainable aquaculture practices. This analysis primarily focuses on the ability of aquaculture to fulfill the demands of a growing population without worsening the stresses on marine ecosystems, while acknowledging the continued need for legal and sustainable capture fisheries. This paper takes stock of where fisheries management is at the moment, lists the obstacles to aquaculture's expansion, and then delves into some novel approaches that may provide better, more long-term results. In order to protect marine biodiversity, increase economic growth, and guarantee food security, the study recommends better management practices, better research and training, and substantial investment in aquaculture.

Frankic, Anamarija & Hershner, Carl. (2003) ^[4]. More and more, as aquaculture becomes more commonplace around the world, people are starting to realize that sustainable aquaculture takes into account not just the physical aspects of the ecosystem, but also the economic and social factors that affect it over time. Professionals in the field have learned that in order for aquaculture to be sustainable, it must not only maximize advantages but also reduce negative effects on society and the environment. Consequently, society should prioritize protecting the quality of the environment for aquaculture, and sustainable aquaculture development should be pursued in a way that is ecologically sustainable and maintains the quality of the environment for other users. Sustainable aquaculture activities in coastal locations that utilize natural coastal habitats and ecosystems are highlighted in this study, which also offers a brief overview of the global development of aquaculture in the last decade. There are some important suggestions made, including what should be done next, based on the current national and international initiatives to encourage sustainable aquaculture.

3. Research Methodology

3.1 Research Design

To investigate how improving the skills of frontline fisheries

workers can aid in the promotion of sustainable aquaculture development, this study used a descriptive and analytical research strategy based on a survey approach. Given its suitability for use in real-world fisheries extension settings, this methodology allows for the systematic gathering of data pertaining to skills, training exposure, and perceived sustainability outcomes.

3.2 Population and Sample

Staff members working in aquaculture-related roles (*e.g.*, fish farming extension, hatchery management, pond supervision, farmer advisory services, etc.) made up the study's population. The study's sample size was 110 people working in the fishing industry on the front lines.

To ensure a representative cross-section of frontline workers (such as technical assistants, field supervisors, and fisheries extension officers), stratified random selection was used to choose the sample. The findings were more representative and applicable to a wider context because of this method.

3.3 Variables of the Study

- **Independent Variable:** Improvements in technical, managerial, communicative, digital, and environmental management abilities for frontline fisheries workers.
- **Dependent Variable:** Advancement in sustainable aquaculture (including better productivity, less environmental impact, use of best management techniques, and improvement of livelihoods).
- **Control Variables:** Age, educational qualification, work experience, and training exposure.

3.4 Tools and Techniques of Data Collection

A structured questionnaire created for the research was used to gather primary data. The following sections made up the questionnaire, which included both open-ended and Likert-scale questions:

1. Respondents' demographics
2. Current proficiency in aquaculture and fish farming
3. Participation in training and skill development programs
4. The effect of skill development on long-term success in aquaculture

4. Data Collection Procedure

Subject availability dictated the method of data collection, which included both in-person visits and online surveys. Everyone who took part in the study gave their prior informed consent, and their answers would remain private. Consistency was ensured by carrying out the data collection process throughout a set period.

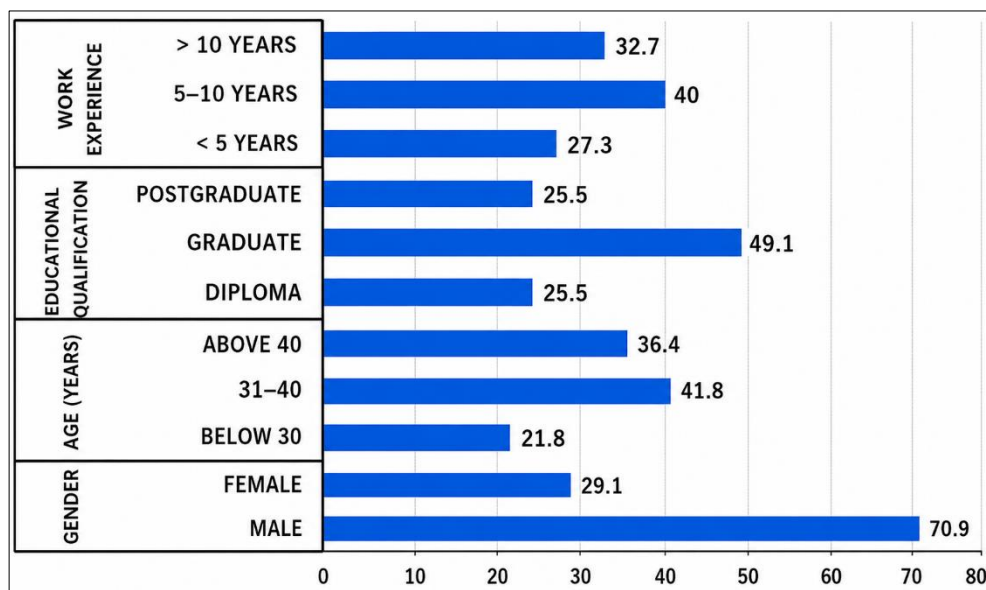
4.1 Statistical Techniques Used

Data was coded and analyzed with the use of suitable statistical programs. We used the following statistical methods:

- **Descriptive Statistics:** Statistical measures that characterize the traits and proficiency levels of the respondents (frequency, percentage, mean, and standard deviation).
- **Correlation Analysis:** To investigate how skill development relates to the advancement of sustainable aquaculture.

Table 1: Demographic Profile of Frontline Fisheries Employees (N = 110)

Variable	Category	Frequency	Percentage
Gender	Male	78	70.9
	Female	32	29.1
Age (years)	Below 30	24	21.8
	31-40	46	41.8
	Above 40	40	36.4
Educational Qualification	Diploma	28	25.5
	Graduate	54	49.1
	Postgraduate	28	25.5
Work Experience	< 5 years	30	27.3
	5-10 years	44	40.0
	> 10 years	36	32.7

**Fig 1:** Demographic Profile of Frontline Fisheries Employees (N = 110)

The gender, age, education level, and years of experience of 110 frontline fishery workers are detailed in Table 1. There is a clear gender gap in the frontline responsibilities of the fisheries industry, as 70.9% of the respondents are male and 29.1% are female. Employees seem to be mostly mature and experienced, with the largest age group being those between 31 and 40 years old (41.8% of the total), followed by those over 40 (36.4%). The comparatively low proportion of younger staff is reflected in the 21.8% of employees who are under the age of 30. In terms of educational

qualifications, we have a reasonably well-qualified workforce with over half of the respondents being graduates (49.1%), and an equal number of diploma holders and postgraduates (25.5%). The frontline staff has significant professional exposure, as the highest share of employees (40.0%) have 5-10 years of experience, followed by 32.7% with more than 10 years. There appears to be a healthy mix of seasoned pros and fresh faces in the fishing industry, as 27.3% of the sample consists of employees with less than five years of experience.

Table 2: Mean Skill Levels of Frontline Fisheries Employees

Skill Dimension	Mean	SD	Rank
Technical fish farming skills	3.82	0.64	I
Environmental & sustainability skills	3.67	0.71	II
Communication & extension skills	3.54	0.68	III
Managerial & planning skills	3.42	0.73	IV
Digital & ICT-based skills	3.21	0.76	V
Overall Skill Enhancement	3.53	0.58	—

(Scale: 1 = Very Low to 5 = Very High)

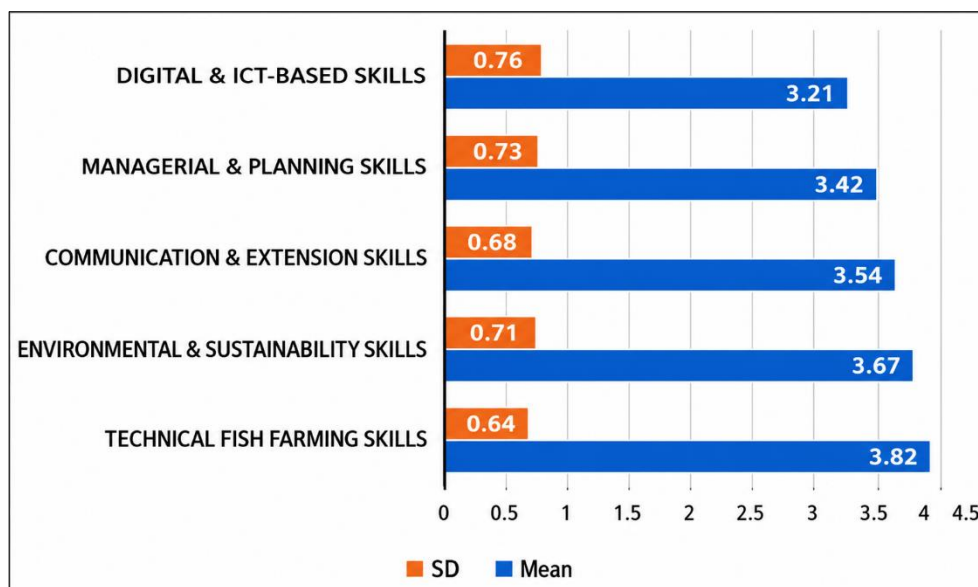


Fig 2: Mean Skill Levels of Frontline Fisheries Employees

In Table 2, you can see the average, standard deviation, and rank of the many skill characteristics that frontline fisheries workers possess. The results show that technical fish farming abilities rank first with the highest mean score (Mean = 3.82, SD = 0.64), indicating that frontline staff in core fisheries operations have significant technical competence. After this comes environmental and sustainability abilities, which indicate a decent degree of knowledge and action pertaining to sustainable fisheries management (Mean = 3.67, SD = 0.71), rated second.

Having intermediate proficiency in communicating with fishers and spreading technical information is indicated by the third position (Mean = 3.54, SD = 0.68) of communication and extension skills. With an average score of 3.42 (SD = 0.73), managerial and planning abilities come in at number four, suggesting a somewhat lower level of

competence in these areas. Digital and ICT-based abilities had the fifth-lowest mean score (Mean = 3.21, SD = 0.76), indicating a lack of proficiency with digital tools and ICTs. Frontline fishery professionals generally have moderate to high levels of abilities, according to the overall skill enhancement mean score of 3.53 (SD = 0.58). However, there is definitely room for improvement, especially in digital and managerial competence.

Table 3: Training Exposure of Frontline Fisheries Employees

Training Exposure	Frequency	Percentage
No formal training	18	16.4
1-2 training programs	46	41.8
3-4 training programs	32	29.1
More than 4 programs	14	12.7
Total	110	100.0

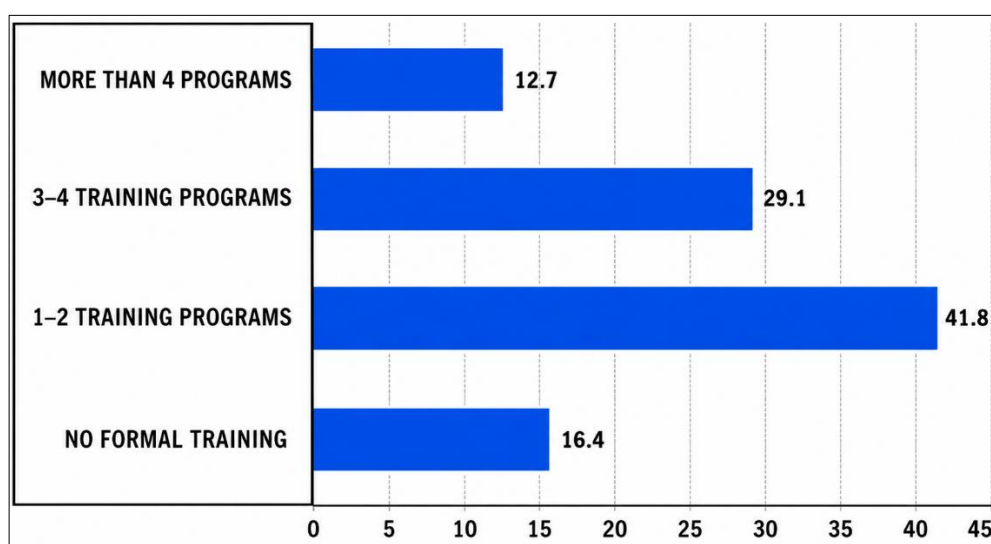


Fig 3: Training Exposure of Frontline Fisheries Employees

The training exposure of frontline fishery staff is shown in Table 3. The majority of employees have gotten some formal capacity-building help, as the findings show that 41.8% of respondents have attended one to two training sessions. Continuing professional development is moderately important for a large portion of the workforce,

as 29.1% of employees have participated in three to four training programs.

There appears to be a training deficit among a sizeable proportion of frontline personnel, since 16.4% of respondents claim to have no formal training. It appears that there is a lack of exposure to advanced or recurrent training

options, as only 12.7% have attended more than four sessions. There needs to be more systematic and inclusive training programs to improve skills and professional

competence in the fisheries industry as a whole. The table shows that most frontline workers get some training, but the amount and quality of that training is inconsistent.

Table 4: Level of Sustainable Aquaculture Development Outcomes

Sustainability Indicator	Mean	SD
Adoption of best aquaculture practices	3.76	0.65
Improved fish productivity	3.71	0.69
Environment-friendly farming methods	3.63	0.72
Efficient resource utilization	3.58	0.70
Livelihood improvement of farmers	3.69	0.67
Overall Sustainability Score	3.67	0.61

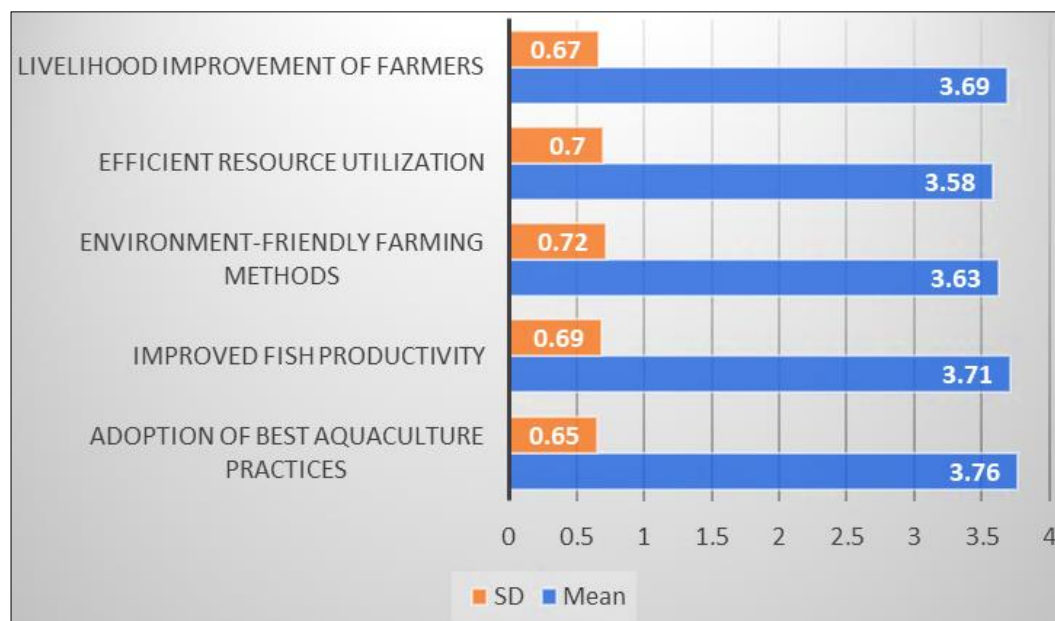


Fig 4: Level of Sustainable Aquaculture Development Outcomes

In Table 4, we can see how several sustainability metrics rank the results of sustainable aquaculture development. With the highest mean score (Mean = 3.76, SD = 0.65) for adoption of best aquaculture practices, the results demonstrate that stakeholders place a reasonably great focus on these practices. There was a considerable improvement in fish productivity (Mean = 3.71, SD = 0.69) and an improvement in farmers' livelihoods (Mean = 3.69, SD = 0.67), indicating that sustainable aquaculture programs are favorably impacting farmers' socio-economic situations and production efficiency.

Environmentally friendly farming methods have a moderate level of adoption, with a mean score of 3.63 (SD = 0.72) for these practices. On the other hand, efficient resource utilization shows a slightly lower mean score of 3.58 (SD = 0.70), suggesting that there is room for improvement in making the most of inputs like water, feed, and energy. With a mean score of 3.67 (standard deviation = 0.61), sustainable aquaculture development outcomes are moderate to high. However, the wide range of indicators shows that targeted interventions are needed to improve resource efficiency and environmental sustainability in addition to productivity and livelihood gains.

Table 5: Correlation between Skill Enhancement and Sustainable Aquaculture Development

Variable	r-value	p-value	Significance
Overall skill enhancement vs sustainability	0.64	<0.01	Significant
Technical skills vs sustainability	0.68	<0.01	Significant
Environmental skills vs sustainability	0.61	<0.01	Significant
Digital skills vs sustainability	0.49	<0.05	Significant

Sustainable aquaculture development outcomes are correlated with skill augmentation of frontline fisheries staff, as shown in Table 5. The findings show that improving overall skills is strongly correlated with sustainability ($r = 0.64$), with a statistically significant relationship at the 1% level ($p < 0.01$). Sustainable aquaculture development outcomes are positively correlated with frontline staff's overall skill levels.

Technical competence is crucial for fostering efficient and sustainable aquaculture methods, as it demonstrates the strongest positive link with sustainability among the specific skill aspects ($r = 0.68$, $p < 0.01$). Fostering eco-friendly aquaculture development relies on environmental awareness and sustainability-oriented abilities, which are strongly correlated with sustainability outcomes ($r = 0.61$, $p < 0.01$). The use of digital and ICT-based tools contribute significantly to sustainable aquaculture, although to a lesser

extent than technical and environmental skills. This is supported by a moderate yet statistically significant positive correlation between digital skills and sustainability ($r = 0.49$, $p < 0.05$). The results show that improving the technical, environmental, and digital competencies of frontline fisheries workers is crucial for a sustainable aquaculture industry.

5. Conclusion

The current research shows that improving the skills of frontline fisheries workers is essential for promoting sustainable aquaculture development. Frontline workers have a major impact on the adoption of sustainable farming methods, better aquaculture practices, and effective use of resources because they are the main link between fisheries institutions and fish farmers. The study's results show that sustainable aquaculture results are better achieved when workers have strong technical, environmental, and communication abilities.

The findings confirm that competent and well-trained fisheries workers are better able to promote best management practices, increase fish productivity, and encourage environmentally friendly farming methods, and they also show a strong positive correlation between skill enhancement and sustainability indicators. The significance of sustainability-oriented training and domain-specific fish farming abilities were highlighted as the strongest predictors of sustainable aquaculture development among the numerous skill characteristics.

Additionally, the study proves that exposure to training is a key factor in skill improvement. Frontline fishery workers who took part in various training programs were far more competent than their less-trained counterparts. This discovery highlights the importance of ongoing, organized, and outcome-driven programs for enhancing capacity, as opposed to isolated training sessions.

Human resource development is a critical factor in achieving sustainable growth in aquaculture, according to the study's conclusion. Improve the performance of frontline fisheries employees by strengthening skill enhancement activities. This is especially important in the areas of digital technologies, climate-resilient practices, and environmental management. To guarantee sustainable aquaculture development, improved livelihoods, and ecological balance, fisheries extension agencies and policymakers should prioritize long-term skill development programs.

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