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RESEARCH PAPER

Assessment of Aqua Drugs Utilization in Aquaculture from South-West Bangladesh: A Comprehensive Study of Practices and Implications for Aquatic Health Management

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Abstract

To assess the current usage of aqua drugs and chemicals in enhancing the well-being of aquaculture in Khulna, Satkhira, and Bagerhat districts, a survey was conducted through questionnaire interviews involving 150 representative aquaculture farms. Spanning from January to June 2022 in Bangladesh, the survey encompassed six distinct sub-districts across three different districts. Various aquaculture systems, including finfish polyculture (FP), prawn (*Macrobrachium rosenbergii*) and finfish polyculture (PP), shrimp (*Penaeus monodon*) and finfish polyculture (SP), shrimp, prawn, and finfish polyculture (SPP), and semi-intensive shrimp culture (SS), were considered during the sampling process. The findings revealed the use of 123 aqua drugs and chemicals, classified into seven groups: water quality modifiers (31), disinfectants or sanitizers (13), oxygen supplier (12), therapeutics (10), probiotics (12), antibiotics (23), and feed supplements and growth promoters (22). Livelihood variables such as age, farm size, experience, education, training, source of water, water exchange frequency, crop duration, and production were recorded and analyzed to comprehend the current social context associated with shrimp farming. The diseases were categorized into viral, bacterial, fungal, parasitic, nutritional, and environmental with specific examples provided under each category.

Introduction

A proliferation in aquaculture practices is adopting by aqua farmers in Bangladesh because of its economically profitable and viable aqua farming technologies while noticeable declination was observed in the wild catch (Khan et al., 2016; Rashid et al., 2019; Hasan et al., 2021b, 2021c; Aziz et al., 2021). Additionally, the aqua industry is also meeting up the demand for animal protein, generating employment opportunities, reducing poverty, and enhancing the socio-economic well-being of individuals are crucial factors that contribute significantly to the national economy (Nasim et al., 2012; Ahmed et al., 2012). The Satkhira, Khulna, and Bagerhat districts of the northeast region of Bangladesh are among the top areas for shrimp cultivation. With the expansion of aquaculture in this region, an increasing number of drugs and chemicals are being employed to manage the health of aquatic animals, with over 78 percent of shrimp farms currently situated in these districts (Hossain et al., 2018). In Bangladesh, shellfish (shrimp & prawn) farming is an occupation that provide supports 1.15 million people in farming activities and subsequently employs another 5.2 million people throughout the production cycle (DoF, 2019). Due to its superior benefit-cost ratio, shrimp farming has become the preferred choice for numerous farmers in the south-western region of Bangladesh, leading to its widespread adoption (Rasha et al., 2019; Khan et al., 2021). As aquaculture has grown, the use of additional chemicals in managing the health of aquatic animals has increased (Dey et al., 2020). As a result of the use of aquaculture drugs and chemicals, several issues have arisen (Ali et al., 2018). Aquaculture production in Bangladesh has experienced rapid growth on embryo development stimulation, natural production, feed composition through the aid of various aquaculture drugs and chemicals (Dipu et al., 2014).

One of the primary concerns that have arisen in recent times is the escalation in disease prevalence, attributed to the clustering of farms, the stocking of low-quality post-larvae, reliance on shared water sources, and inadequate implementation of bio-security measures (Ananda Raja et al., 2012; Hasan and Haque, 2020; Hasan et al., 2020b). The application of unauthorized medications in farmed aquatic species, as well as the erroneous application of licensed pharmaceuticals (but not for aquaculture) facilitate the possibilities of resistant bacteria to antibiotics that can harm vital human organs (Rahman et al., 2014; Rahman et al., 2023). The significance of maintaining biosecurity and managing health at the farm level to mitigate the effects of diseases has been widely acknowledged (Ananda Raja et al., 2012), but the actual execution has always been complicated (Hasan et al., 2013). Many people agree that using pharmaceuticals and other substances in aqua farming is advantageous for a variety of reasons. They are crucial for improving natural production, treating illness, regulating good health, and stimulating development among other things (Hossain et al., 2018).

Numerous reports claim that many aquaculture producers in Southeast Asia use medications without additionally implementing the necessary precautions (Ali et al., 2016; Li et al., 2016). Aquaculture consultants, pharmaceutical and feed company representatives, and chemical sellers form a substantial part of the marketing chain responsible for delivering their products to end users (Sharker et al., 2014). Various international organizations have expressed grave concerns about the improper use of these chemicals, which frequently results in the emergence of Antimicrobial Resistance (AMR) and poses significant risks to public health (Mishra et al., 2017; Patil et al., 2022a & 2022b). Improper usage of chemicals can contribute to occupational health risks and pose potential threats to human health, including respiratory and skin issues, allergies, the danger of intoxication, and the spread of infectious diseases (Phu et al., 2016; Sumon et al., 2016). Zoonotic pathogens like Vibrio spp. and Aeromonas spp. pose distinct threats to both humans and crustaceans, as highlighted in the study by Watterson et al. (2012). Currently, shrimp farmers in Bangladesh generally lack awareness of occupational health hazards (Ali et al., 2016). While the significance of implementing farm-level biosecurity and health management practices to mitigate the impact of diseases is well acknowledged (Hasan et al., 2013), the actual execution of these measures has not consistently been uncomplicated.

The objective of this study is to identify the aqua drugs and chemicals used in the management of aquatic animal health especially for FP: finfish polyculture; PP: prawn & finfish polyculture; SP: shrimp & finfish polyculture; SPP: shrimp, prawn & finfish polyculture; SS: semi-intensive shrimp culture in the grater southern region and to evaluate the types of aqua drugs and whether farmers are adhering to the recommended dosages.

Materials and Methods

Study Area

From January 2022 to June 2022, a study was conducted in the Khulna, Satkhira, and Bagerhat districts along with six different upazilas (sub-districts). These areas were selected because they play a significant role in shrimp and prawn production and are regularly visited by aquaculture drug merchants and pharmaceutical company representatives (Figure. 1).

Data Collection Process

This study targeted the fish farmers from the southwest part of Bangladesh since they are the largest contributors of shrimp, prawn, and finfish aquaculture in Bangladesh (Table 1). The study focused on six upazilas (sub-districts) of three districts, namely Khulna, Satkhira, and Bagerhat, in the southwest part of Bangladesh (Figure 1). Dumuria and Paikgacha upazila from Khulna; Debhata and Shyamnagar upazila from Satkhira; Fakirhat and Mongla upazila from Bagerhat district were randomly selected for the questionnaire survey. A sample of 150 fish farmers from twelve villages was drawn proportionately and randomly among the lists obtained from Upazila Fisheries Offices. Prior to the final survey, the questionnaire was pretested among five fish farmers, and necessary modifications were made in light of the study's objectives. The questionnaire included information regarding fishermen's various livelihood capitals, production characteristics, fish diseases with their treatment histories and so on. In addition to interviews, a focus group discussion (FGD) between 10–12 fish farmers in each village were conducted. FGD was chosen as one of the participatory rural appraisals (PRA) tools to obtain an overview of specific issues, including the problems associated with the use of aquaculture drugs. Ten key informant interviews (KII) with drug dealers, private company personnel working on treatment of fish diseases, and Upazila Fisheries Officer (UFO) were also established to collect secondary data and verify the necessary data.

In this comprehensive aquaculture research study, the variables under investigation encompass a diverse range of cultivation practices. Finfish Polyculture (FP, N=36) involves the simultaneous farming of multiple finfish species, while Prawn & Finfish Polyculture (PP, N=29) combines prawns and finfish in the aquaculture system. Shrimp & Finfish Polyculture (SP, N=23) specifically explores the co-cultivation of shrimp and finfish, and the Shrimp, Prawn & Finfish Polyculture (SPP, N=43) represents a more intricate system involving the simultaneous cultivation of shrimp, prawns, and finfish. Additionally, the study delves into the nuances of Semi-intensive Shrimp Culture (SS, N=19), focusing on a targeted approach to shrimp cultivation. The Overall category (n=150) aggregates data from all these different aquaculture systems and secondary data from different organization, providing a comprehensive and holistic perspective. The varying sample sizes across categories reflect the diversity and distribution of these practices within the studied population.

Data Processing and Analysis

All secured data were analyzed using descriptive statistical methods and tabular methods. Short tables were created, and data gathered from multiple sources were imported into an MS Excel spreadsheet, IBM statistics SPSS (version 25.0). The tabular technique was applied for processing the data by using simple statistical tools like percentages and averages. The data were checked for normality and used to assess significant differences between farm categories for each parameter using a one-way analysis of variance (ANOVA) followed by the Bonferroni multiple range test. Using Monte Carlo permutation tests within the Redundancy Analysis (RDA) option, we investigated the relationship between the various farming characteristics' individual parameters and the dataset reporting disease/symptom occurrence. The spreadsheets were matched to the preliminary

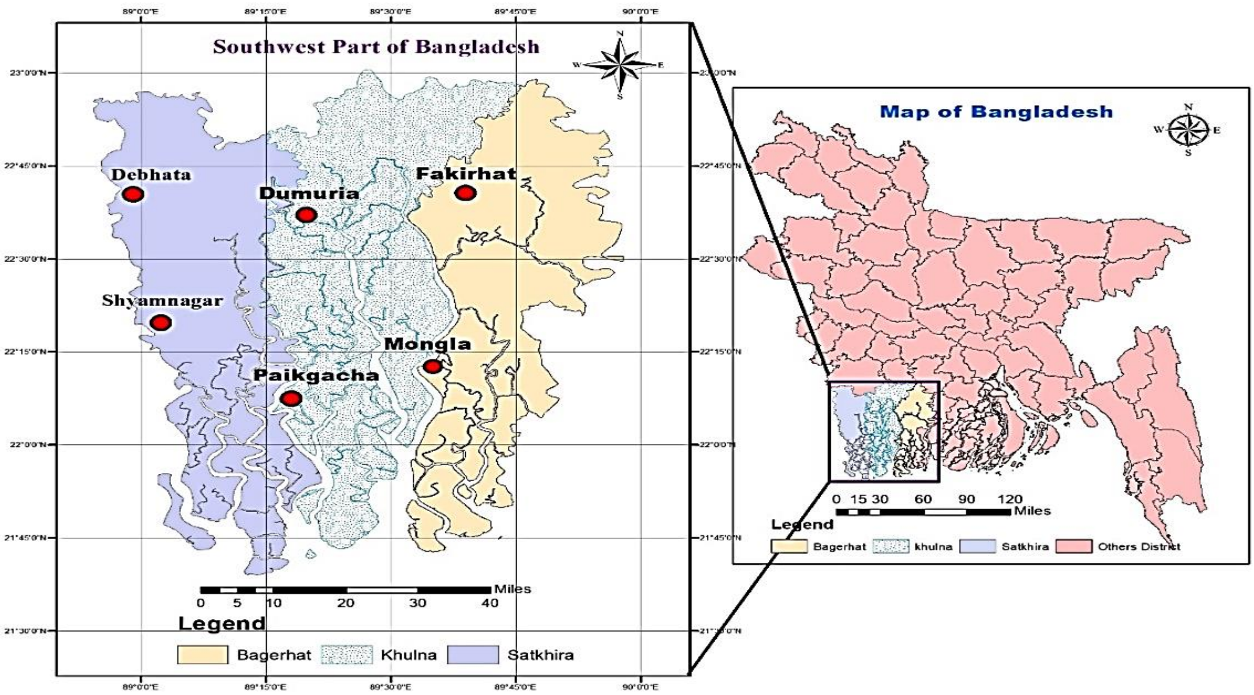

Figure 1: Map of the Study area.

Table 1: Study areas and sampling size.

District	Sub-districts	Target groups	Sample size				
			FP (36)	PP (29)	SP (23)	SPP (43)	SS (19)
Khulna	Dumuria	Fin fish farmers, Prawn farmers, Shrimp farmers	9	6	7	8	3
	Paikgacha	Fin fish farmers, Prawn farmers, Shrimp farmers	7	6	5	6	3
Satkhira	Debhata	Fin fish farmers, Prawn farmers, Shrimp farmers	8	3	3	8	2
	Shyamnagar	Fin fish farmers, Prawn farmers, Shrimp farmers	5	4	4	7	3
Bagerhat	Fakirhat	Fin fish farmers, Prawn farmers, Shrimp farmers	4	2	2	8	4
	Mongla	Fin fish farmers, Prawn farmers, Shrimp farmers	3	8	2	6	4
							Total: 150

*(FP: Finfish Polyculture; PP: Prawn & Finfish Polyculture; SP: Shrimp & Finfish Polyculture; SPP: Shrimp, Prawn & Finfish Polyculture; SS: Semi-intensive shrimp culture).

information at several points during the interview to confirm that the inputted data was accurate.

Results

Variables

This data presents a snapshot of the demographic and professional characteristics of individuals involved in aquaculture, revealing interesting patterns across different variables. The average age of participants varies, with the highest observed in the Shrimp & Finfish Polyculture group (40.12±12.30) and the lowest in the Semi-intensive Shrimp Culture group (35.21±10.12). Farm size displays notable differences, with the Semi-intensive Shrimp Culture group (1.89±1.56) having the largest farms compared to the Prawn & Finfish Polyculture group (0.72±0.27), which has the smallest. Experience levels are relatively consistent across groups, ranging from 4.70±4.37 to 7.53±5.38, indicating a moderate level of experience in aquaculture practices. Education levels vary, with the highest mean observed in the Semi-intensive Shrimp Culture group (7.84±3.45) and the lowest in the Shrimp & Finfish Polyculture group (5.23±3.56). These findings provide valuable insights into the demographic diversity and expertise within different aquaculture practices, shedding light on potential correlations between age, farm size, experience, and education levels among practitioners in the field (Table 2).

Training

The data illustrates the percentage distribution of training in two key aspects, culture and health management, across different aquaculture practices. For culture-related training, percentages range from 30.6% to 39.7%, with the highest observed in the Prawn & Finfish Polyculture group. However, concerning health management training, all groups exhibit a uniform 0%, indicating a potential gap or lack of specific training in this critical aspect across the studied aquaculture practices (Table 2).

Stocking Density

The stocking density data for shrimp, prawn, and finfish across different aquaculture practices reveals significant variations. In the Shrimp & Finfish Polyculture (SP) group, the stocking density is notably high at 150.13±16.76, while the Semi-intensive Shrimp Culture (SS) group records an even higher density of 914.74±76.19. Prawn & Finfish Polyculture (PP) stands out with a stocking density of 115.93±13.20, and Finfish Polyculture (FP) follows with 21.25±3.15. Interestingly, the Shrimp, Prawn & Finfish Polyculture (SPP) group maintains a moderate stocking density of 65.58±6.67. These variations underscore the diverse approaches to stocking density in different aquaculture systems, possibly influenced by species interactions, farm size, or management practices (Table 2).

Table 2: Respondent and production characteristics of studied farm groups (values expressed as mean ± SD excluding percentages which are expressed as mean values).

Variables	FP (N=36)	PP (N=29)	SP (N=23)	SPP (N=43)	SS (N=19)	Overall (n=150)
Age	39.08±10.38	40.07±11.54	38.22±11.22	40.12±12.30	35.21±10.12	38.95±11.81
Farm Size	1.37±.97 ^{ab}	0.72±.27 ^{a}	1.36±.99 ^{ab}	1.22±.89^{ab}	1.89±1.56^{b}	1.26±1.05
Experience	7.53±5.38^{a}	7.34± 5.65^{a}	4.70± 4.37^{a}	7.33 ±5.53^{a}	6.32 ±5.60^{a}	6.85± 5.39
Education	6.11±2.62 ^{ab}	7.00 ±3.96 ^{ab}	5.74 ±2.80 ^{ab}	5.23± 3.56 ^{a}	7.84 ±3.45^{b}	6.19 ±3.39
Training (%)						
Culture	30.6	39.7	32.6	38.4	34.7	35.2
Health management	0	0	0	0	0	0
Source of water						
Rain %	69.4	86.2	47.8	55.8	0	51.84
Under Ground Water %	13.8	6.9	4.3	16.3	10.52	10.36
Surface Water %	16.6	6.9	47.8	27.9	89.5	37.74
Water exchange freq.	1.14±.73 ^{b}	0.38±.37 ^{a}	0.52±.38 ^{a}	.40±.97 ^{a}	1.32±.77 ^{b}	0.75±.397
Crop duration (month)	11.0 ±1.625^{c}	8.0± .00 ^{b}	3.65 ±0.49 ^{a}	7.91 ±0.61 ^{b}	4.00 ±0.00 ^{a}	7.52 ±2.72
Stocking Density/decimal						
Shrimp	0	0	150.13±16.76 ^{c}	90.93±8.68 ^{b}	87.11±7.32^{b}	109.39±35.33
Prawn	0	115.93±13.20^{c}	0	65.58±6.67^{b}	0	90.70±28.42
Fin fish	21.25±3.15^{c}	4.90 ±1.26^{b}	5.26±.70^{b}	5.37±1.84^{b}	0	8.37±7.56
Production (MT/Ha)						
Shrimp	0	0	1.3±.076^{a}	0.67±0.021^{a}	9.98±1.984^{b}	1.34±0.421
Prawn	0	1.6±.064^{c}	0	0.86±.028^{b}	0	1.05±.028
Finfish	6.91±.712^{c}	0.51±.013^{b}	0.61±.013^{b}	0.80±.091^{b}	0	1.73±2.601

*FP: Finfish Polyculture; PP: Prawn & Finfish Polyculture; SP: Shrimp & Finfish Polyculture; SPP: Shrimp, Prawn & Finfish Polyculture; SS: Semi-intensive shrimp culture. Mean values followed by different superscript letters indicate significant differences.

Production (MT/Ha)

The production data, measured in metric tons per hectare, showcases distinct outcomes across shrimp, prawn, and finfish in various aquaculture systems. Notably, Semi-intensive Shrimp Culture (SS) demonstrates the highest production at 9.98±1.984, highlighting its efficiency in yield. Prawn & Finfish Polyculture (PP) follows with a significant production of 1.6±.064, while Shrimp & Finfish Polyculture (SP) achieves 1.3±.076. Finfish Polyculture (FP) also contributes to production, with 6.91±.712, emphasizing its role in overall yield. Shrimp, Prawn & Finfish Polyculture (SPP) records moderate production at 0.86±.028. The data underscores the diversity in production outcomes, likely influenced by stocking density, species interactions, and management practices within each aquaculture category (Table 2).

Water Quality Modifiers

The table depicts the use of various water quality management strategies in different aquaculture systems. Zeolite is predominantly applied in Finfish Polyculture (FP) and Prawn & Finfish Polyculture (PP) systems, while Gypsum is more prevalent in Shrimp & Finfish Polyculture (SP) and Shrimp, Prawn & Finfish Polyculture (SPP) practices. Probiotics and chemicals find greater use in FP, with minimal application in other systems. Bleaching Powder is widely used in PP, SP, and SPP, and exclusively in Semi-intensive Shrimp Culture (SS), suggesting its significance in shrimp-focused systems. Yucca schidigera sees diverse use across all systems, with the highest application in Semi-intensive Shrimp Culture. Methionine and other acids are primarily employed in FP. These variations highlight the nuanced approaches to water quality management in different aquaculture practices, reflecting considerations for species-specific needs and environmental conditions (Table 3).

Disinfectants

The disinfectant usage across different aquaculture systems is outlined in this experiment (Table 3). Benzalkonium Chloride is the predominant disinfectant in all categories, with the highest concentration in Semi-intensive Shrimp Culture (SS) at 100%. Povidone Iodine sees varied use across systems, notably absent in SS. Sodium Thiosulfate is employed in Finfish Polyculture (FP), Prawn & Finfish Polyculture (PP), Shrimp & Finfish Polyculture (SP), and Shrimp,

Table 3: List of chemicals applied by FP, PP, SP, SPP and SS farmers (% of farmers those reported the use of each chemical)

Active Ingredients	**Farm Group (%)**					**Overall mean**
1. Water Quality modifiers	**FP**	**PP**	**SP**	**SPP**	**SS**	
Zeolite	11.41	12.67	8.21	8.53	0	8.164
Gypsum	14.56	6.88	14.13	9.33	100	28.98
Probiotics and chemicals	9.05	4.275	3.225	5.25	0	4.36
Bleaching Powder	25	36.2	34.8	36.05	100	46.41
Yucca schidigera	10.54	8.78	12.06	8.8	31.57	14.35
Methionine & other acids	8.35	1.7	4.35	1.15	0	3.11
2. Disinfectants						
Benzalkonium Chloride	11.91	13.28	14.27	14.31	100	30.754
Povidone Iodine	6.95	13.8	10.85	12.8	0	8.88
Sodium Thiosulfate	20.8	20.65	15.2	16.25	0	14.58
Others	8.3	17.2	17.4	11.6	0	10.9
3. Oxygen suppliers						
Sodium Percarbonate	12.97	14.54	13.01	13.98	15.21	13.94
Hydrogen Peroxide	13.9	11.5	14.47	10.87	17.57	13.66
4. Therapeutics						
Ivermectin	77.84	55.86	54.72	81.09	18.87	57.676
Organic Mixture	15.3	13.8	13.05	10.5	0	10.53
Trichlorfon & Citrocin	16.7	8.6	13.05	17.45	0	11.16
Methylene blue	8.3	10.3	8.7	18.6	0	9.18
5. Probiotics						
Bacteria	8.81	9.2	13.03	9.11	100	28.03
6. Growth Promoters						
Protein & fatty acid	10.425	6.025	5.4	7	7.9	7.35
Vitamin & Minerals	5.96	7.4	7.01	6.79	12.97	8.026
Mannan Oligosaccharides	12.5	12.05	8.65	11.65	10.55	11.08
Natural Spirulina	7.43	8.03	8.67	10.87	5.3	8.06
7. Antibiotics						
Oxytetracycline	8.07	6.19	6.5	4.66	0	5.084
Amoxicillin	5.57	4.57	2.87	3.9	0	3.382
Erythromycin	9.27	8.03	10.1	9.3	0	7.34
Chlortetracycline	7.4	5.73	8.67	8.56	0	6.072
Ciprofloxacin	5.55	2.87	4.34	5.79	0	3.71
Sulfamethoxazole & Trimethoprim	8.3	17.2	4.3	4.7	0	6.9
Enrofloxacin	2.5	0	0	0	0	0.5

Prawn & Finfish Polyculture (SPP) but not in Semi-intensive Shrimp Culture. Other disinfectants are applied across FP, PP, SP, and SPP but are absent in SS. This data underscores the specific disinfection strategies employed in each aquaculture category, reflecting tailored approaches to maintaining a healthy and sterile environment for aquatic species.

Therapeutics

The data presents the prevalence of different disease treatment methods in various aquaculture systems. Ivermectin is widely utilized across all categories, with the highest application in Shrimp, Prawn & Finfish Polyculture (SPP) at 81.09%. Organic Mixture is employed to a lesser extent and is absent in Semi-intensive Shrimp Culture (SS). Trichlorfon & Citrocin are used in Finfish Polyculture (FP), Shrimp & Finfish Polyculture (SP), and SPP but not in Semi-intensive Shrimp Culture. Methylene blue finds varied use, with the highest percentage in SPP. This information highlights the diverse disease treatment approaches, with Ivermectin being a common choice across all systems, and other methods tailored to the specific needs and challenges within each aquaculture category.

Antibiotics

The data provides insights into the use of antibiotics in different aquaculture systems. Oxytetracycline, Amoxicillin, Erythromycin, Chlortetracycline, Ciprofloxacin, and Sulfamethoxazole & Trimethoprim are commonly employed across Finfish Polyculture (FP), Prawn & Finfish Polyculture (PP), Shrimp & Finfish Polyculture (SP), and Shrimp, Prawn & Finfish Polyculture (SPP). However, the Semi-intensive Shrimp Culture (SS) category stands out with a notable absence of antibiotic use, suggesting a potentially different disease management approach in this system. This data emphasizes the need for sustainable practices and careful antibiotic management in aquaculture, acknowledging variations in treatment strategies based on the specific characteristics of each aquaculture system.

Disease Status

This comprehensive figure outlines the prevalence of various diseases in different aquaculture systems (Figure 2). In the Viral category, diseases like Fish Pox, VHS, SVC, WSSV, and Yellow Head exhibit varying degrees of occurrence across the systems, with notable absence in Semi-intensive Shrimp Culture (SS) for some viruses. Bacterial diseases, including Columnaris, Vibriosis, AHPND (EMS), Streptococcosis, HPN (Hepato Pancreatic Necrosis), FTR (Fin and Tail Rot disease), and IHN (Infectious Hepatopancreatic Necrosis), demonstrate diverse patterns with certain diseases more prevalent in specific systems. Nutritional/Environmental issues like Broken Ant, Soft Shell, and Black Gill are more pronounced in Prawn & Finfish Polyculture (PP) and Shrimp & Finfish Polyculture (SP). Fungal diseases such as EUS, Cotton Shrimp, and Saprolegniasis vary in occurrence, with Semi-intensive Shrimp Culture (SS) notably free of fungal issues. Parasitic diseases like Argulosis, Gyrodactylosis, Dactylogyrosis, and Protozoan Disease are prevalent in Prawn & Finfish Polyculture (PP) and Shrimp & Finfish Polyculture (SP). Additionally, there are instances of

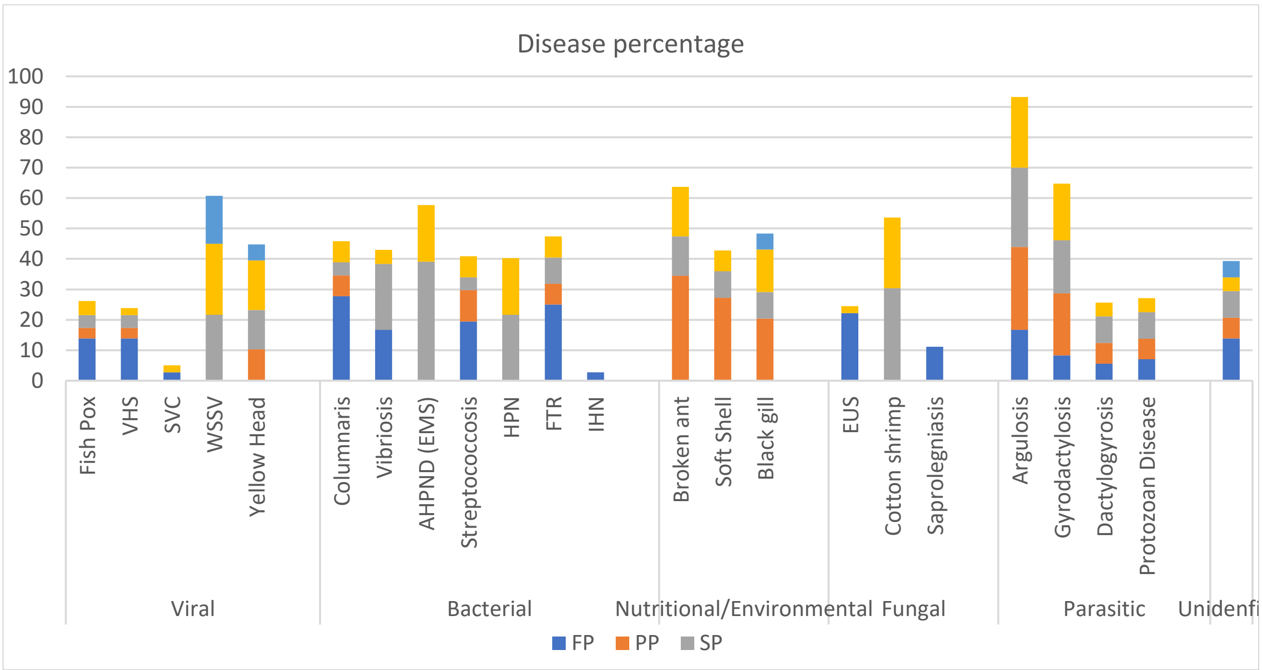

Figure 2: Percentage of fish diseases reported by farmers.

unidentified diseases across all systems. This data emphasizes the complexity of disease dynamics in aquaculture and underscores the need for tailored management strategies in different aquaculture categories (Figure 2).

Among the finfish diseases or syndromes reported by farmers Columnaris, Vibriosis, EUS, Fin and tail rot, Streptococcosis, and Argulosis were the most common diseases. In the finfish polyculture technique (FP), maximum 27.8% of farmers reported Columnaris disease followed by Fin and tail rot (25%), and streptococcosis (19.4%). Farm size has a strong positive correlation with Vibriosis, Columnaris, EUS, and Fish pox disease in the finfish polyculture technique. Water exchange frequency and experience have a positive correlation with Argulosis and Streptococcosis in the finfish polyculture (FP) technique as shown in Figure 3(c). Five different types of diseases or syndromes for shrimp species were reported by farmers from the study area. Among them, maximum of 39.1% farmers reported AHPND (Acute hepatopancreatic necrosis disease) also known as early mortality syndrome (EMS) in the shrimp polyculture (SP) techniques followed by cotton shrimp disease (30.4%), and WSSV (21.7%). In the shrimp polyculture technique (SP), water exchange frequency has a positive correlation with WSSV and AHPND but these diseases are negatively correlated with farm size and experience as shown in Figure 3(a). Yellow head disease, Broken antenna and rostrum, soft shell disease, and Black gill disease were reported as the main problem by the farmers for prawn species in the study area. In the prawn polyculture technique (PP), 34.5% of farmers reported broken antenna and rostrum disease followed by soft shell disease (27.2%), and black gill disease (20.4%). Water exchange frequency has a positive correlation with soft shell disease, Broken antenna and rostrum disease but yellow head disease showed a negative correlation with experience in prawn polyculture technique (PP) as shown in Figure 3(b).

Active Ingredients

This catalog provides a comprehensive list of active ingredients and corresponding drug names in various categories related to aquaculture practices. In the realm of water quality management, Zeolite, Gypsum, Probiotics and chemicals, Bleaching Powder, Yucca schidigera, and Methionine & other acids are detailed with specific product names. Disinfectants such as Benzalkonium Chloride, Povidone Iodine, Sodium Thiosulfate, and others are categorized alongside their

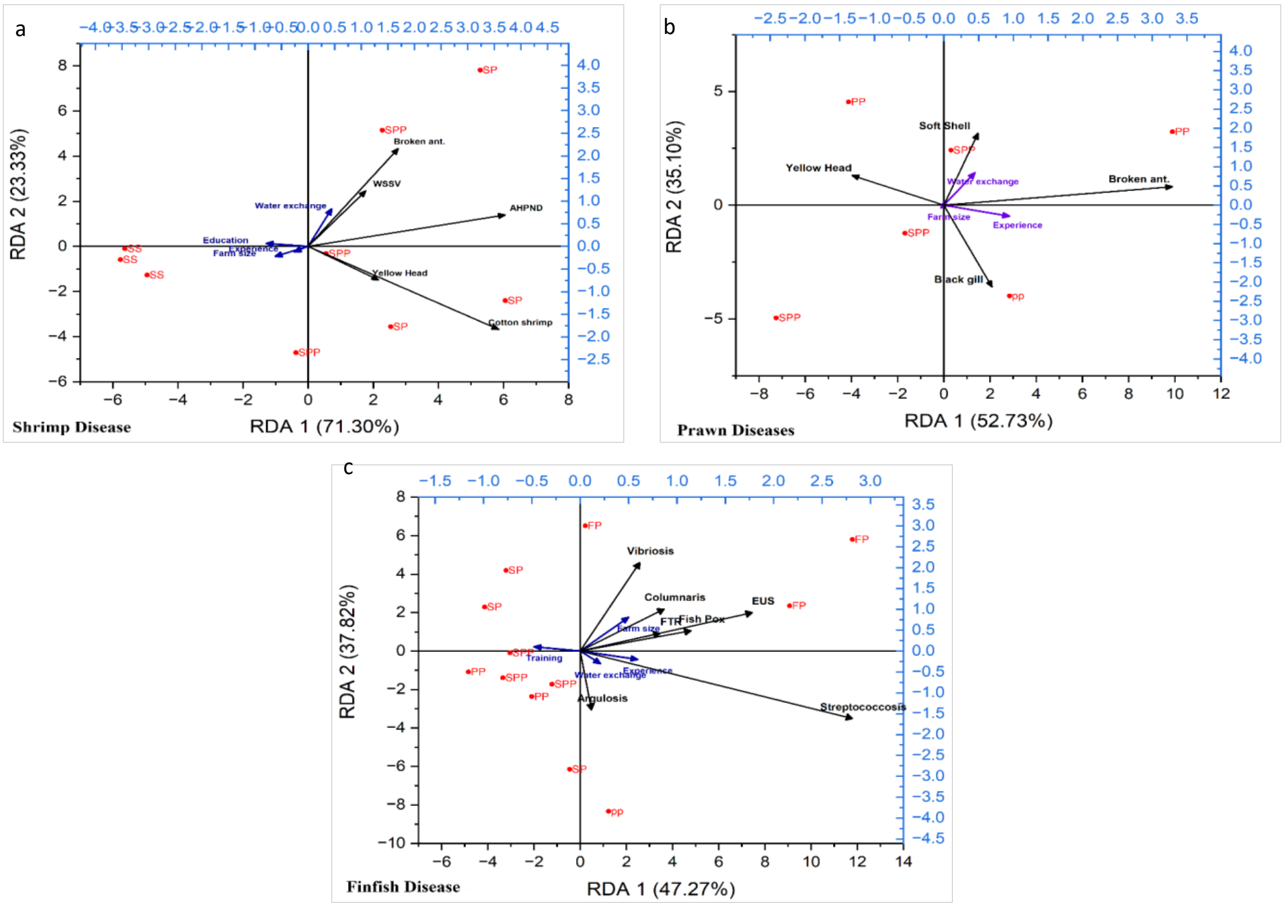

Figure 3 (a, b, c): RDA ordination diagrams derived for shrimp, prawn, and finfish from each of the culture technique with the disease history dataset. Nominal independent variables are represented by triangles and continuous independent variables by empty arrows. The arrows point in the direction of maximum correlation, and the length of the arrow is related to the strength of the correlation with the chemical variation shown by the diagram. In general, the longer the arrow, the higher the relation of the tested variable to the variation of the disease occurrence dataset.

respective drugs. Oxygen supply methods include Sodium Percarbonate and Hydrogen Peroxide. Disease treatment options encompass Ivermectin, Organic Mixture, Trichlorfon & Citrocin, and Methylene blue. Probiotics, Antibiotics, and Growth Promoters are also outlined, with details on specific products and their active ingredients. This comprehensive compilation serves as a valuable resource for understanding the diverse array of pharmaceuticals and treatments used in aquaculture practices, shedding light on the intricate and specialized nature of managing aquatic environments and species (Table 4).

Discussion

Distinct aqua-medicine usage patterns arise across various regions, shaped by cultural practices, species preferences, and economic considerations. In this particular study, a survey encompassed 150 fish farms, gathering information on 123 aqua-medicines, drugs, and chemicals. The findings indicated that active aquaculture zones were susceptible to a variety of infectious diseases, including bacterial, parasitic, fungal, viral, and nutritional ailments (Mishra et al., 2015; Sahoo et al., 2013; Mohan and Bhatta, 2002). As the demand for fish production rises and intensive fish farming methods become more prevalent, aquatic animals face various health challenges. These issues primarily stem from deteriorating environmental conditions, increased stress levels, and the introduction of infectious agents (Mishra et al., 2017). Farmers in the regions employ a diverse array of antibacterial agents, antiseptics, and water sanitizers to effectively combat diseases and minimize production losses. Additionally, various pesticides and insecticides are applied to address the concern of fish parasitic infestations, which has become a significant issue throughout the entire region. Numerous authors have documented the utilization of a

Table 4: List of most frequently used drugs under different categories recorded from the studied area.

Group name	No	Drug name	Dosage	Active ingredients	Source
Water Quality					
Zeolite	10	Zeofresh, Aqua Rock, Aquapure, Mega zeo plus, JV Zeolite, Zeolite Gold, Zeo Prime, Zeorich, Geotox, Matrix	Spread throughout the pond byhand; 200gm/dec/m depth.	SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O	Fish Tech, EON
Gypsum	3	Greencal Aqua, Green Lime, Aqua Cal	Spread throughout the pond by mixing with water; 15kg/acre/m water depth	$CaSO_4$	ACI Animal Health
Probiotics and chemicals	5	Pond Life, AQUA 4, Optibloom, Bio Pond, Ecomax	Spread throughout the pond by hand;100 gm/dec/m depth	SiO_2, Al_2O_3, Fe_2O_3, CaO,MgO, Na_2O, *Yucca Schidigera* extract, Probiotic	ACI Animal Health
Bleaching Powder	2	Sadic, Belching Powder	Spread throughout the pond by mixing with water; 1.8kg/acre/4ft water depth	Belching Powder Ca(OCl)Cl	Finish
Yucca schidigera	9	Youlax Solution, Pond kleen, Bio-Aqua 50, Ukasol Aqua, Gasonex Plus, Yuka, Gasonil, Ammonil, Gastrap	Spread throughout the pond by mixing withwater;100ml/33dec/m water depth	*Yucca Schidigera*	Square Pharma. Ltd.
Methionine & other acids	2	DE-PH, PHD	Spread throughout the pond by mixing with water; 700ml/acre/4ft water depth	Methionine, lactic Acid, Citric Acid, Formic Acid, Propionic Acid, Butyric Acid,	ACI Animal Health
Disinfectant					
Benzalkonium Chloride	7	Aquakleen, Pathonil, Timsen, Polguard, Micronil, Sunsure, Bacsol-V	Spread throughout the pond after mixing with water; 500ml/33dec/3-6ft water depth	Tetradecyl Trimethyl Ammonium Bromide: 6.6 gBKC: 20% Amino Nitrogen (as Glycine): 10000 ppm	Square Pharma. Ltd.
Povidone Iodine	3	Viodin Vet 10, Povidone vet, Unidine	Spread throughout the pond after mixing with water; 400ml/33dec/3-6ft water depth	Povidin Iodine	Square Pharma. Ltd.
Sodium Thiosulfate	2	Virex, Water Clear	Spread throughout the pond after mixing with water; 200gm/33dec/3-6ft water depth	Potassium monopersulphate50%, Sodium dichloroisocyanurate 5%	ACI AnimalHealth
Others	1	Cidekill	Spread throughout the pond after mixing with water; 200ml/33dec/3-6ft water depth	Gluteraldehyde15%, Dimethylcocobenzyl ammonium chloride 10%	ACI Animal Health
Oxygen Suppliers					
Sodium Percarbonate	9	Oxylife Tablet, Oxylife Granular, ACI-Ox, Oxy more, Oxygold, Oxyrich, Oxy-Ren, Oxy-A, Oxytop	Spread throughout the pond;General oxygen deficiency:300- 400gm/acre Acute Oxygen Deficiency:600-700gm/acre	Sodium carbonate per-oxyhydrate-12.5%	Square Pharma. Ltd.
Hydrogen Peroxide	3	Oxymax, Oxy Flow, Oxygrow	Spread throughout the pond; 250-500gm/acre	H_2O_2, 10%	EON
Therapeutics					
Ivermectin	5	Verkil vet, AG mec 3, Acimec 1%, A-Mectin Vet, Para Safe Vet	Spread after mixing with adequate water; 2ml/dec./3ft water depth	Ivermectin BP 3%	Argon Animal Health
Organic Mixture	2	Eucabiotics, Parakleen	Spread after mixing with adequate water; 100ml/33dec/m water depth	Organic mixture	ACI Animal Health
Trichlorfon & Citrocin	2	Halor Tid, Argulux	Mixed with feed; 5gm/kg feed for 7days	Citrocin, MOS	ACI Animal Health
Methylene blue	1	Methylene blue	Powder, For the treatment of sudden death after fungal attack	$C_{10}H_{18}ClN_3S.H_2O$	Chemical seller

Table 4. Continued

Probiotics					
Bacteria	12	Protox Aqua, Biomax Power, Aqua photo, Ariake 3, Navio Plus, Dello Max, Active Three H, Profs, Pond care, BioFav Aqua, IKI-IKI, GPA	Spreading throughout the pond after Mixing with adequate sand;1kg/33dec.	*Bacillus subtilis Alcaligenes denitrificans Lactobacillus helvetiusLactobacillus lactic Saccharomyces cerevisiae*	Square Pharma. Ltd.
Antibiotics					
Oxytetracycline	10	Otetra Vet 20, Otetra Vet 50, Renamycin, Bactitab, Vetomycin, Oxysentin 20%, Oxin WS, Tetra vet, OTC vet Powder, Active OTC	Mixed with feed;5gm/kg feed	OxytetracyclineHydrochloride-500	SquarePharma. Ltd.
Amoxicillin	3	Acimox (vet) powder, Renamox 30% (vet), Augment Vet	Mix with feed; 1gm/kg feed	Amoxicillin trihydrate	ACI Animal Health
Erythromycin	3	Erisen Vet, Erocot, Micronid	Mix with feed; 50-80gm/100kg feed	Erythromycin Thiocyanate, Sulfadiazine, Trimethoprim	Opsonin Agrovet
Chlortetracycline	3	CTC, Eska CTC, Active CTC	Mix with feed; 200-300gm/100kg feed	Chlortetracycline Hydrocloride	Opsonin Agrovet
Ciprofloxacin	2	Ciprocin Vet, Ciproflox	5ml/kg feed for 5 days	Ciprofloxacin	Opsonin Agrovet
Sulfamethoxazole & Trimethoprim	1	Cotrim Vet	0.5 mg/kg body weight	Sulphamethoxazole + trimethoprim	SquarePharma. Ltd
Enrofloxacin	1	Enroflox DS	5 or 10 mg enrofloxacin/kg body weight	Enrofloxacin	SquarePharma. Ltd
Growth Promoter					
Protein & fatty acid	4	Aqua Bind, Growth gel, Grow Fast, Spa jelly	Mix with feed;10-15gm/kg feed	Protein, Omega 3 & Omega 6 fatty acid, Cholesterol,Calcium, Vitamin D_3, Carotenoid	SquarePharma. Ltd
Vitamin & Minerals	13	Cevit Aqua, Square Aquamix, Panvit Aqua, Rena C, Eskavit C, GP fish gel, Acimix Super Fish, Nutrigel, Protimin, Liquavit Aqua, Safegut, AquaVit Premix, Active Boost	Mix with feed;10-15gm/kg feed	Vitamin A 500000 IU; Vitamin $D_3$100000 IU; Vitamin B_1 160 mg; Vitamin B_2 100mg; Vitamin B_6 100mg; Nicotinamide 1g; Vitamin B_5 500 mg; Ascorbic Acid 5g; Minerals, Amino Acid, Anti-Oxidants, East powder	SquarePharma. Ltd
Mannan Oligosaccharides	2	Myoboost, Aqua Boost	Mix with feed; 500gm/ton feed	Organic acid and derivates salt, β-Glucan, Mannan Oligosaccharide	Elanco
Natural Spirulina	3	Acilina, Eskalina, Nutrilina Aqua	Mix with feed; 3-5gm/kg feed	100% Natural Spirulina	Opsonin
	Total 123				

variety of drugs, chemicals, and feed supplements in aquaculture practices (Chowdhury et al., 2015; Rahman et al., 2014; Sharker et al., 2014; Chowdhury et al., 2012; Faruk et al., 2004). These are employed not only to prevent diseases and enhance production but also for the purpose of health management in hatcheries (Costello et al., 2001; Joshua et al., 2002; Cabello, 2006) In addition to antibiotics, commonly reported chemicals in aquaculture include sodium chloride (NaCl), formalin ($CH2O$), malachite green ($C23H25ClN2$), methylene blue ($C16H18ClN3S$), potassium permanganate ($KMnO4$), hydrogen peroxide ($H2O2$), and glutaraldehyde ($C5H8O2$) (Pathak et al., 2000; Subasinghe et al., 2000). In addition to their role in disease control, numerous aquaculture drugs find substantial applications in various aspects such as pond construction (Dodd, 2017), soil and water management (Dugan et al., 2022), enhancing aquatic productivity (Rico et al., 2012), formulating feeds (Paranamana et al., 2015), manipulating reproduction (Söffker et al., 2012), promoting growth (Rahman et al., 2017), and adding value to the final product (Maqsood et al., 2013). A variety of chemicals are accessible for application in aquaculture, serving both as disinfectants and as a means to enhance health management practices.

The comprehensive list of these chemicals, along with their active ingredients, can be found in (Table 4). In European nations, the predominant anti-parasitic drugs employed for sea lice control include Dichlorvos, Azamethiphos, Hydrogen peroxide, Ivermectin, Emamectin, Cypermethrin, Deltamethrin, Teflubenzuron, with Diflubenzuron being the active ingredient (Costello et al., 2001; Ananda Raja et al., 2020; Ananda Raja et al., 2022; Ananda Raja et al., 2023). Nevertheless, there is a lack of published reports regarding the utilization of aquadrugs, chemicals, and formulations in aquaculture in countries other than those mentioned. Rahman, (2014) documented the application of Geotox, Zeolite, Zeocare, Lime, MegaZeo, Bio Aqua, Aquanone, Zeo prime by various farmers in Bangladesh for pond preparation and water quality management. According to Chowdhury et al. (2012), lime, zeolite, fish toxin, insecticides, and various fertilizers were employed for pond preparation and water quality management in the Noakhali district. Sharker et al. (2014) also pointed out that the majority of chemicals were utilized for oxygen supply, including Bio-ox, Best Oxygen, Oxygen Plus, Oxyflow, Oxylife, Oxymax, Oxymore, and Oxyplus. The primary active ingredient in these products was the oxidizing agent hydrogen peroxide (Ma et al., 2023). Oxymax was commonly applied to alleviate hardness and eliminate toxic gases in fish culture ponds (Faruk et al. 2004; Rahman et al., 2023). In 2008, 40 shrimp farmers along the south-west coast of Bangladesh reported utilizing almost 140 distinct products (Shamsuzzaman et al., 2012). Similarly, a study in India, involving 265 farms, 36 aqua shops, and 18 drug manufacturing units, documented the availability of 364 aqua-medicines, drugs, and chemicals for farmers to address disease challenges (Mishra et al., 2017). In 2002, a study conducted in Thailand documented that 76 shrimp farmers employed a total of 290 different products, averaging 13 products per farm (Gräslund et al., 2003). Similarly, in Mexico during the same year, 23 shrimp farms were reported to use 106 different products, averaging the application of 42 products per farm (Lyle-Fritch et al., 2006). SP (Shrimp polyculture) farmers employed a diverse array of pesticides in contrast to SPP (Shrimp and Prawn polyculture) and PP (Prawn polyculture), utilizing them not only to eliminate unwanted organisms but also to combat diseases affecting shrimp. All the farmers confirmed that they refrained from utilizing any chemicals prohibited by the 2011 national code of conduct regulating aquaculture in Bangladesh, as outlined by the Department of Fisheries (DoF, 2011). Typically, these pesticides, originally intended for pest control in rice crops, pose high toxicity to non-target aquatic insects and crustaceans, as emphasized by Sumon et al. (2016). In this current investigation, various diseases and syndromes have been identified as primary hindrances to the advancement of aquafarming in Bangladesh (Karim et al., 2012; Paul & Vogl, 2011). This may be linked to the rise in stocking densities and the extensive use of feed, leading to a decline in water quality (MacRae et al., 2002). Additionally, the diminished effectiveness of disinfection methods in the presence of substantial organic matter and the potential development of antibiotic resistance contribute to this phenomenon (Ali et al., 2018).

Previously shrimp farming faces constraints due to its environmental and socioeconomic repercussions (Paul and Vogl, 2011). The effectiveness of organic shrimp farms can be enhanced by factors such as increased age, higher educational attainment, and previous experience in aquaculture (Paul and Vogl, 2012). In this experimental area, there is a lack of training in health management. It could be indicative of a gap in knowledge or resources dedicated to health management practices in the context of hatchery management. The well-being of shrimp farmers is intricately linked to the effective utilization of land and water resources, as well as the preservation of broader natural assets (Paul and Vogl, 2013). Hatchery owners face the imperative of addressing factors like stocking density, soil and water quality, post-larvae quality, and employing polyculture techniques to ensure not only a sustainable use of water resources but also the maintenance of healthy soil quality (Willer and Kilcher, 2010). The incidence of shrimp diseases poses a risk to economic returns in Bangladesh (Alam et al., 2007). Effective management strategies, including limited stocking density in organic farming, play a crucial role in mitigating shrimp losses attributed to diseases (Paul and Vogl, 2012; Chowdhury et al., 2024). Practices employed in organic aquaculture, according to Tacon and Brister (2002), have the potential to achieve a high level of disease resistance and infection prevention. Additionally, the health of shrimp is significantly affected by the quality of saline water, emphasizing the importance of ensuring safe water conditions to prevent pollution and degradation (Islam et al., 2004a; Islam, 2003). Despite this, there remains a deficiency in the presence of a systematically organized adaptation strategy aimed at fostering the sustainability of shrimp farming in the coastal region of southwest Bangladesh (Rahman and Islam, 2013; Pokrant, 2014). As a result, shrimp farming is being explored as a viable option for adapting to the rising salinity levels in this particular region (Amoako et al., 2016). Hence, there is a need for enhanced institutional support to effectively execute the government's policy and facilitate the sustainable advancement of shrimp hatchery in the coastal region of southwest Bangladesh. Shrimp policies should extend beyond technical and financial considerations, prioritizing the welfare of small-scale shrimp farmers (Akber et al., 2017). Finally, it is essential for both governmental and non-governmental entities to proactively lead the way in implementing improved management practices and adhering to the guidelines outlined in aquaculture policies.

Conclusion

Our study on aqua medicine use in South-West Bangladesh reveals its widespread application, from probiotics to antibiotics, for boosting productivity and disease control. However, this raises concerns about food safety, environmental impact, and drug resistance. Balancing aquaculture growth with ecosystem and public health protection is crucial. A more sustainable and responsible approach is needed for the industry's long-term viability

Ethical Statement

Not applicable.

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Author Contribution

Kishor Kumar Tikadar: Conceptualization, Writing-Original draft; Methodology and Data Analysis; Sanzib Kumar Barman: Resources, Review and editing; Shoriful Islam: Validation; Md. Sohan Khan: Data collection; Rasel Mia: Data curation; MD Zobayer Rahman: Writing-Original draft preparation.

Conflict of Interest

Authors have no conflict of interest. Authors are fully respectful to each other and they have no partial conflict during the research and no claim over the decision of journal in future decisions.

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