



A HANDBOOK FOR AQUAFARMERS

THE ADVANCES IN BRACKISHWATER AQUACULTURE



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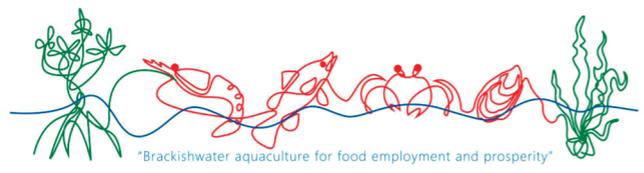
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Editors

M. Kumaran
K.P. Kumaraguru vasagam
Kuldeep Kumar Lal



ICAR - CENTRAL INSTITUTE OF BRACKISHWATER AQUACULTURE
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Chennai, 600028, India

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PREFACE

Brackishwater aquaculture, the farming of euryhaline shrimps, finfishes, mudcrab and seaweeds for food production is an important activity for nutritional security, employment generation, societal development, exports and national economy. Shrimp farming is the most common component of brackishwater aquaculture, being practiced in all the coastal states and inland saline areas in about 1.92 lakh ha with an estimated production of 11.64 lakh tonnes. Despite its often stated advantages, shrimp farming has its own risks and challenges in the form of diseases, seed quality issues, production system hazards, raising inputs cost and low sale price which all together put the farmer in the crossroads. While it is difficult to provide immediate solutions for the farmers constraints, efforts are being made constantly to facilitate the farmers in the form of technology exposure, capacity development and policy interventions in tackling their on-farm and off-farm challenges. ICAR-Central Institute of Brackishwater Aquaculture is the nodal research institution providing technical backstopping for the brackishwater aquaculture sector. The outcomes of dedicated research efforts in the form of advances in farming practices, production systems, alternative species for diversification, disease prevention and management, smart farming solutions, market-led farming and enabling support for accessing institutional credit and insurance are being communicated in more than one mode to the farming community to combat the challenges faced by them. In this line, this book on 'The advances in brackishwater aquaculture - A handbook for aquafarmers' containing topics on the present status and export prospects of shrimp farming, feed management, water quality management, disease management, smart farming and real-time data based shrimp farm management, shrimp crop insurance and diversification possibilities of brackishwater aquaculture with Indian white shrimp, mudcrab and finfishes is brought out for the benefit of stakeholders. Further, the modules of newly launched mobile application 'Report Fish Diseases App' which connect the farmers directly to the National Surveillance Programme on Aquatic Animal Diseases under the Prime Minister Matsya Sampada Yojana (PMMSY) are also included in the book. In addition, chapters on the initiatives and support from the national institutions *Viz.*, the Coastal Aquaculture Authority, National Fisheries Development Board and Marine Products Export Development Authority for shrimp farming are included in the revised edition. We sincerely hope that the stakeholders would make use of this book in updating their knowledge and adopt the farming advancements articulated for enhancing the production and profitability of brackishwater aquaculture.

Editors

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COASTAL AQUACULTURE AUTHORITY (CAA) AND ITS ROLE IN REGULATING AND PROMOTING SUSTAINABLE COASTAL AQUACULTURE IN INDIA

K. C. Devasenapathi and P. Sankara Rao

Genesis of the Coastal Aquaculture Authority (CAA)

The Supreme Court, in its verdict in Writ Petition No. 561 of 1994 (Jagannathan vs. Union of India), raised concern about the environmental protection of coastal areas and directed the Central Government to constitute an authority to protect ecologically sensitive coastal areas as well as to promote sustainable and responsible coastal aquaculture in the country. As per the directions, the Coastal Aquaculture Authority (CAA) was constituted under the Coastal Aquaculture Authority Act, 2005 (Act No. 24 of 2005), enacted by the Parliament of India, which received the assent of the Hon'ble President of India on the 23rd day of June 2005.

The CAA is functioning with a mandate to ensure that coastal aquaculture shall not cause any detriment to the coastal environment, to promote responsible coastal aquaculture in compliance with the provisions contained under the Act, Rules, Regulations, and Guidelines and also to protect the livelihood of the various sections of the people living in the coastal areas. The Authority is empowered to make regulations for the construction and operation of aquaculture units in coastal area; register aquaculture farms and hatcheries, inspect them to ascertain their environmental impact; remove or demolish coastal aquaculture farms that cause pollution, etc., Through these regulatory measures, CAA aims to promote environmentally responsible and socially acceptable coastal aquaculture

Amendment of the Principal CAA Act, 2005

The urgent need to remove impediments in practices of coastal aquaculture in areas falling under the Coastal Regulation Zone (CRZ) and to decriminalise the Act was identified by the Department of Fisheries, Ministry of Fisheries, Animal Husbandry & Dairying, Government of India. It was also felt that the country has to support diversification of coastal aquaculture by including newer forms of coastal aquaculture within the ambit of CAA for harnessing the full potential of coastal waters in the country. To make provisions to address all the operational issues and to reaffirm that coastal aquaculture and its allied activities are permissible within the CRZ under the CRZ notifications, the Government of India notified the Coastal

Aquaculture Authority (Amendment) Act, 2023 (No 27 of 2023) on 14th August, 2023 and came into force on 12th September, 2023 (S.O. 3977(E) dated 07th September, 2023). The CAA(Amendment) Act 2023 can be considered as one of the biggest support extended by the Government of India for the sustainable development of the coastal aquaculture sector in a manner that is harmonious with the coastal environment.

Impact of the CAA (Amendment) Act, 2023 on the development of coastal aquaculture

The CAA (Amendment) Act 2023 has comprehensively covered all activities of coastal aquaculture and removed the ambiguities that existed in the Principal Act, thereby enabling the country to have a well-coordinated and inclusive regulatory regime that forms the basis for sustainable development. One of the major impacts of the Amendment is that it has been successful in removing the ambiguity on aquaculture activities that can be carried out in 'No Development of Zone' which has been plaguing the sector for the last ten years. When the Principal Act was enacted in 2005, the focus was only on farms, especially on shrimp farming in land-based earthen ponds. Necessary Amendments have been made to remove the ambiguity and permitted Hatcheries, Brood Stock Multiplication Centres (BMCs) and Nucleus Breeding Centres (NBC) within the No Development Zone in sync with the CRZ Notifications. The Amendments has also reduced the multi-agency regulatory and compliance burden on coastal aquaculture and reiterated the protection granted under the validation section of the Principal Act. The timely Amendment of the CAA Act has saved the sector to retain the well-established around 550 seed production units and to continue their seed production activity seamlessly, which are supplying quality seed and supporting the growth of shrimp farming in the country.

The CAA Guidelines framed to implement the principal Act are in sync with CRZ notification and do not permit coastal aquaculture activities in the Ecologically Sensitive Areas (ESAs) and Geo-morphological areas for environmental sustainability. While this provision already existed through CAA Guidelines, there was no enabling provision in the Principal CAA Act for its legal validity and effective implementation. Therefore, an express provision has been made in the Amendment which is in harmony with CRZ Notification. This has enhanced clarity and will further ensure that the fragile coastal ecosystems are not tampered with in the name of aquaculture. Registration is the first step to establish traceability, which is demanded by the importing countries and therefore it is essential that all the compliant units are registered, and no one is kept pending because of procedural issues. A 'proviso has been added to register the coastal aquaculture farms established in Government allotted/ assigned land as demanded by some State Governments in view of their

state policies relating to lease tenure. This new provision will support registration of all these small farmers who will get an identity and without difficulty, market their produce, conforming to the needs of an international recognized traceability system. Now the Act has empowered the CAA to appoint Committees for the efficient discharge of its duties and performance of its functions under Act and stakeholders can also become part of the committees. This gives a participatory approach to decision making /implementation of various mandates of the CAA.

Now newer forms of coastal aquaculture, such as cage culture, seaweed culture, bivalve culture etc. have come up, which can only be done in these areas, and which use only temporary structures. These activities are very economically viable and also have the potential for creating large-scale employment opportunities for coastal fisher communities especially fisherwomen. Already several women Self Help Groups are consistently generating income from these small-scale activities through financial support from PMMSY. The economic growth and empowerment of coastal women have been directly impacted by the adoption of these technologies in coastal villages, especially through seaweed farming, cage culture of finfishes and oyster/mussel farming. The amendment in the CAA Act has ensured that these activities are permissible in the creeks, rivers and backwaters within the CRZ. Now, the Government has notified the guidelines for all these newly recognised technologies to ensure that good aquaculture practices are followed by each entrepreneur. With a vision to integrate technological development in remote sensing with coastal aquaculture, the Act amendment has included provisions for aqua-zoning and aqua-mapping.

To protect the interest of the aquaculture farmers by ensuring availability of quality aquaculture inputs, especially certified aquaculture inputs like feed, probiotics and other healthcare products, which are free from pharmacologically active substances or antimicrobial agents, aquaculture inputs have been brought under the ambit of the CAA Act. The Coastal Aquaculture Authority is now empowered to prohibit the use of aqua-inputs, which contained banned substances for the protection of the coastal environment and public health. This regulatory mechanism will also bring in global recognition to the country since there will be regulations in place right from the start of the production cycle.

Disease prevention is key to the success of coastal aquaculture and provisions have been made to provide for disease-free and genetically improved stocks and systems to promote sustainable coastal aquaculture. Accordingly, specific provisions for Specific Pathogen Free (SPF) certification, establishment of Nucleus Breeding Centre's and Brood Stock Multiplication Centre's which are key to the production of disease-free stocks, have been made in the Act. This will enable the establishment of disease-free systems and the production of genetically improved SPF stocks to

promote sustainable coastal aquaculture. At present, the sector is importing specific pathogen-free brood stock from international empanelled suppliers. The Act has given the powers to the CAA to make regulations for the operation of coastal aquaculture units to ascertain their environmental impact; regulate coastal aquaculture, SPF certification, fixing or adopting of standards for inputs used in aquaculture and for effluents from coastal aquaculture units. This would ensure that guidelines for carrying out good aquaculture practises are in place and are meticulously followed by the stakeholders so that the coastal ecosystem is protected. The Amendment has also included provisions for the environment damage assessment which will enable the penalisation of the violators, upholding the polluter pays principle.

Provisions have now been made to facilitate the farmers and other stakeholders with ease of doing business such as condoning the delay in submitting the application for renewal of the registration with an additional fee to regularise all the coastal aquaculture farms with CAA; simplification of renewal process and now the applicants can directly submit their application for renewal of certificate of registration to CAA without routing through Sub Divisional Level Committee (SDLC) or District Level Committee; issuance of Duplicate certificates in case of lost; issue of registration certificate with transfer of ownership; online application process for ensuring transparency, accountability and issuance of certificates in time. Accordingly, the CAA developed online application and provided access to the farmers to apply online

The Principal CAA was decriminalised and a combination of suitable monetary and other penalties has been included in lieu of imprisonment under the amended Act applying the 'polluter pays principle. In tandem with the amendment of Penalty, consequential provisions have been made for Authorized Officers and Adjudicating Officer, Appellate Authorities. Provisions for appeal against orders passed have also been included since the cases will no longer go to courts where there are system of appeals and revisions. Due care has been taken to ensure that the penalties are not excessive and the upper limit does not exceed the amount already prescribed in the Amended Act. Further, efforts have been made to remove discretionary powers of Adjudicating Officer and Appellate Authorities.

Notification of the Coastal Aquaculture Authority Rules, 2024

In tandem with the CAA (Amendment) Act, 2023, a comprehensive Coastal Aquaculture Authority Rules, 2024 was notified vide G.S.R 33(E) dated 8th January, 2024. The important provisions made under the CAA Rules, 2024 includes simplification of registration process of coastal aquaculture farms by dissolving the State Level Committee and constitution of Sub-Divisional Level Committees (SDLCs) at divisional level in the District and District Level Committees (DLCs) at District

level in all coastal states and UTs for expediting the process of applications and issue certificates within time; simplified renewal process and the farmers can now submit applications directly to the CAA without submitting application to SDLC/DLC concerned; prescribing of the manner of considering application for registration of hatcheries, Nucleus Breeding Centres and Broodstock Multiplications was prescribed; procedure for condoning the delay in submission of application for renewals, issue of duplicate certificates, certificate with transfer of ownership was prescribed; provision to develop online application to facilitate the farmers with online process for registration of their coastal aquaculture units; manner of assessing the cost of damage to environment was prescribed to recover the cost of loss occurred to coastal environment from the concerned unit operators; prescribing the standards and certification of aquaculture inputs and notification of prohibited pharmacologically active substances and antimicrobial agents in aquaculture; provision for health monitoring, disease surveillance and Specific Pathogen Free (SPF) certification of BMCs/NBCs and Hatcheries etc.,

Notification of Guidelines

To promote sustainable coastal aquaculture practices and activities in line with the CAA (Amendment) Act, 2023 and as per the provisions contained under Rule 3 of the CAA Rules, 2024 the following (18) guidelines are developed by the CAA and notified by the Ministry:

- i. Guidelines for regulating coastal aquaculture (S.O. 1496(E) dated 20.03.2024)
- ii. Guidelines for regulating hatcheries and farms for seed production and culture of Specific Pathogen Free *Litopenaeus vannamei* (S.O. 1457(E) dated 15.03.2024)
- iii. Guidelines for seed production and culture of Specific Pathogen Free *Penaeus monodon* (S.O. 1429(E) dated 15.03.2024)
- iv. Guidelines for solid waste management in coastal aquaculture units or activities (S.O. 1458(E) dated 15.03.2024)
- v. Guidelines for certificate of compliance for aquaculture inputs (S.O. 1456(E) dated 15.03.2024)
- vi. Guidelines for the establishment and operation of NBCs & BMCs in India (S.O. 1459(E) dated 15.03.2024)
- vii. Guidelines for the health monitoring, disease surveillance and SPF certification of coastal aquaculture units and stocks in India (S.O. 1479(E) dated 15.03.2024)
- viii. Guidelines for regulating hatcheries and farms for seed production and culture of marine finfishes (S.O. 2897(E) dated 26.06.2024)

- ix. Guidelines for regulating hatcheries and farms for seed production and culture of indigenous shrimp species in marine and brackish water (S.O. 2903(E) dated 26.06.2024)
- x. Guidelines for regulating hatcheries and rearing units for marine/brackish water ornamental organisms (S.O. 2904(E) dated 26.06.2024)
- xi. Guidelines for regulating seaweed seedling production and farming in marine and brackish water (S.O. 3458(E) dated 24.07.2024)
- xii. Guidelines for regulating cage and pen culture of marine/brackish water aquaculture species (S.O. 3462(E) dated 24.07.2024)
- xiii. Guidelines for notifying the aqua zones and aqua mapping (S.O. 3463(E) dated 24.07.2024)
- xiv. Guidelines for regulating seed production and farming of bivalves in marine and brackish water (S.O. 3464(E) dated 24.07.2024)
- xv. Guidelines for assessment of cost for the damage to the environment and cost of demolition and utilization of environment monitoring fund (S.O. 3461(E) dated 24.07.2024)
- xvi. Guidelines for regulating hatcheries and farms for seed production and culture of crab (S.O. 3981(E) dated 29.8.2024)
- xvii. Guidelines for regulating live feed culture units and management in coastal aquaculture (S.O. 3982(E) dated 29.8.2024)
- xviii. Guidelines for regulating Bio-floc, Recirculatory Aquaculture Systems (RAS), and Nursery-based Aqua Farming Systems (S.O. 3983(E) dated 29.08.2024)

Now the country has a comprehensive and robust regulatory framework that covered all the verticals of the coastal aquaculture, which facilitates and promotes the environmentally sustainable coastal aquaculture by harnessing the full potential coastal water resources for economic growth , employment generation to rural people and nutritional security for the nation.

Core Activities and Achievements of the CAA

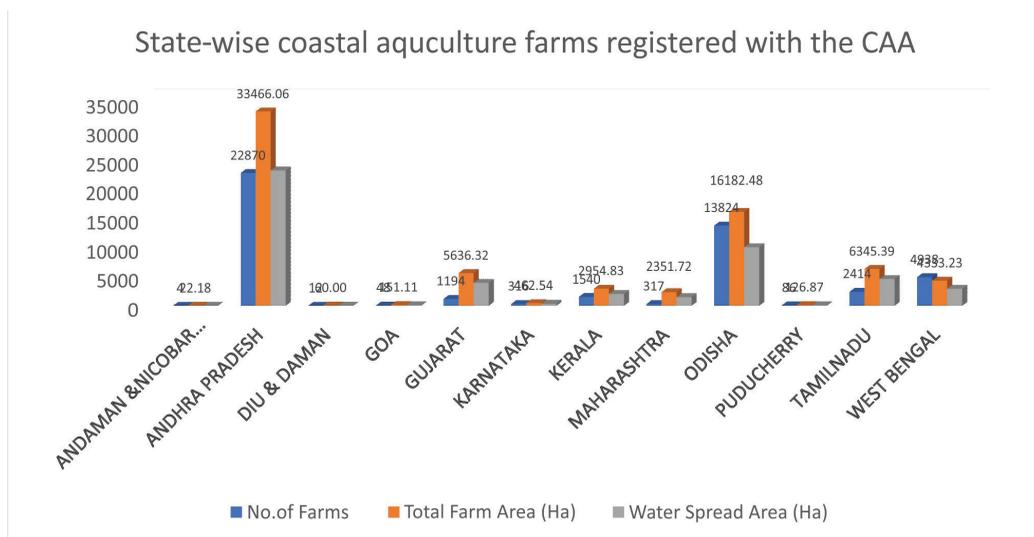
I. Registration of Farms

The CAA, being a regulatory authority, is registering all coastal aquaculture farms with the support of the District Level Committees and Sub-Divisional Level Committees constituted in 75 coastal districts across 9 maritime states and 3 UTs and ensuring that coastal aquaculture activities are carried out in compliance with the provisions prescribed in the CAA Act, its Rules, Guidelines, and Regulations. So far, 47,563 coastal aquaculture farms were registered, covering a total farm area of 72093 ha with a water spread area of 49027 ha. All these registered farms shall

be renewed for every 5 years and about 67% of the farms registered are pending for its renewal. The State wise coastal aquaculture farms registered with the CAA is furnished in the below table.

Coastal Aquaculture Farms Registered with the CAA as on 16th September 2025

S.No	State/UT	No.of Farms	Total Farm Area (Ha)	Water Spread Area (Ha)
1	ANDAMAN &NICOBAR ISLAND	4	22.18	5.29
2	ANDHRA PRADESH	22870	33466.06	23301.22
3	DIU & DAMAN	12	60.00	38.40
4	GOA	48	151.11	109.82
5	GUJARAT	1194	5636.32	3956.42
6	KARNATAKA	316	462.54	351.56
7	KERALA	1540	2954.83	2031.59
8	MAHARASHTRA	317	2351.72	1491.73
9	ODISHA	13824	16182.48	10090.71
10	PUDUCHERRY	86	126.87	95.26
11	TAMILNADU	2414	6345.39	4612.47
12	WEST BENGAL	4938	4333.23	2942.62
	Total	47563	72092.74	49027.09



II. Registration of Seed Production Units

The CAA is mandated to register all coastal aquaculture hatcheries, Nauplii Rearing Hatcheries (NRHs), and live feed units located in coastal areas across the country. A total of 556 units have been registered, which includes 320 hatcheries (*L. vannamei* – 294; *P. monodon* – 20; Scampi-2: Marine Fin fish – 4) and 236 NRHs (*L. vannamei* – 222; *P. monodon* – 14), with a total seed production capacity of about 1.00 lakh million per annum. The CAA has also registered 12 live feed units, which include 3 *Artemia* and 9 Polychaete units. The state-wise hatcheries and live feed units registered with the CAA is furnished in the below tables.

L.vannamei seed production units registered with the CAA as on 31st August 2025

Sl. No	State	L.vannamei seed production units					
		Hatcheries (No.s)	Seed Production Capacity (Million)	NRHs (No's)	Seed Production Capacity (Million)	Total Units (No.s)	Total Seed production capacity (Million)
1	Andhra Pradesh	209	53503	190	19657	399	73160
2	Tamil Nadu	75	14510	19	194	94	14704
3	Odisha	6	1410	13	1390	19	2800
4	Gujarat	3	780	0	0	3	780
5	West Bengal	1	300	0	0	1	300
	Total	294	70503	222	21241	516	91744

P. monodon seed production units registered with the CAA as on 31st August 2025

Sl. No	State	P.monodon seed production units					
		Hatcheries (No.s)	Seed Production Capacity (Million)	NRHs (No's)	Seed Production Capacity (Million)	Total Units (No.s)	Total Seed production capacity (Million)
1	Andhra Pradesh	14	4040	5	990	19	5030
2	Tamil Nadu	4	1000	5	700	9	1700
3	Odisha	0	0	2	205	2	205
4	Gujarat	2	900	1	480	3	1380
5	Karnataka	0	0	1	60	1	60
	Total	20	5940	14	2435	34	8375

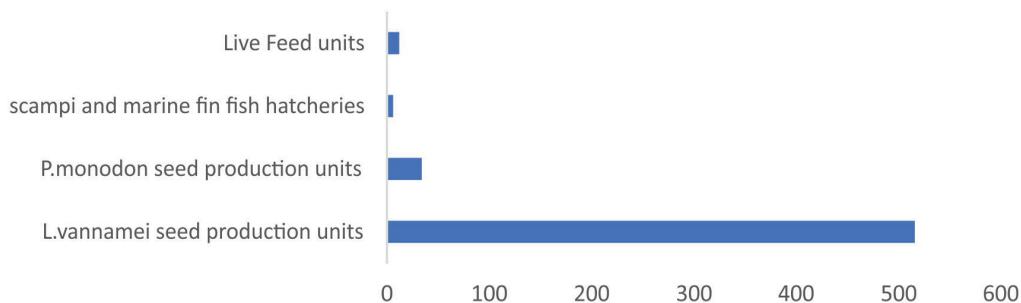
Scampi and Marine fin fish seed production units registered with the CAA

Sl. No	State	Scampi Hatcheries		Marine Fin fish Hatcheries	
		Hatcheries (No.s)	Seed Production Capacity (Million)	Hatcheries (No.s)	Seed Production Capacity (Million)
1	Andhra Pradesh	1	240	2	20
2	Tamil Nadu	1	30	0	0
3	Karnataka	0	0	1	5
4	Gujarat	0	0	1	200
	Total	2	270	4	225

Status of Live Feed units registered with the CAA as on 31st August 2025

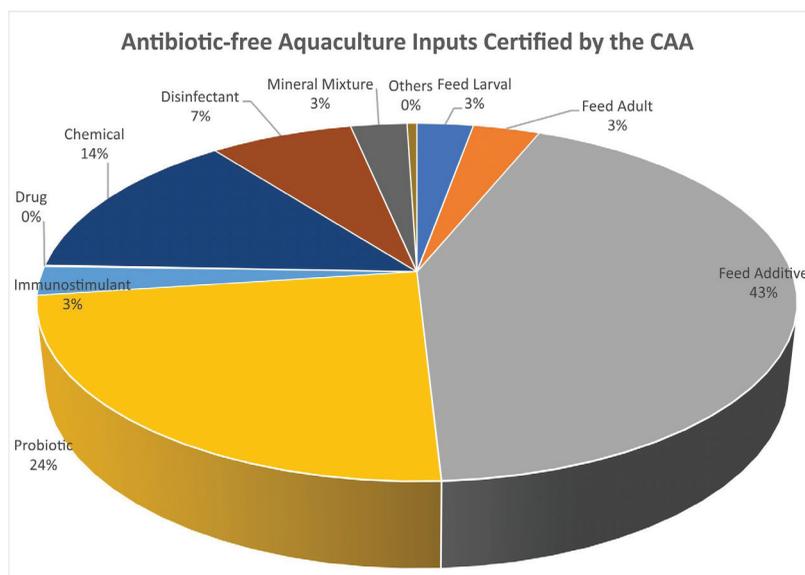
S.No	State	Polychaete Units	Artemia units	Total Live Feed Units
1	Andhra Pradesh	8	3	11
2	Tamil Nadu	1	0	1
	Total	9	3	12

Hatcheries and Live feed units registered with the CAA



III. Issuance of Certificate of Compliance for Antibiotic-Free Aquaculture Inputs

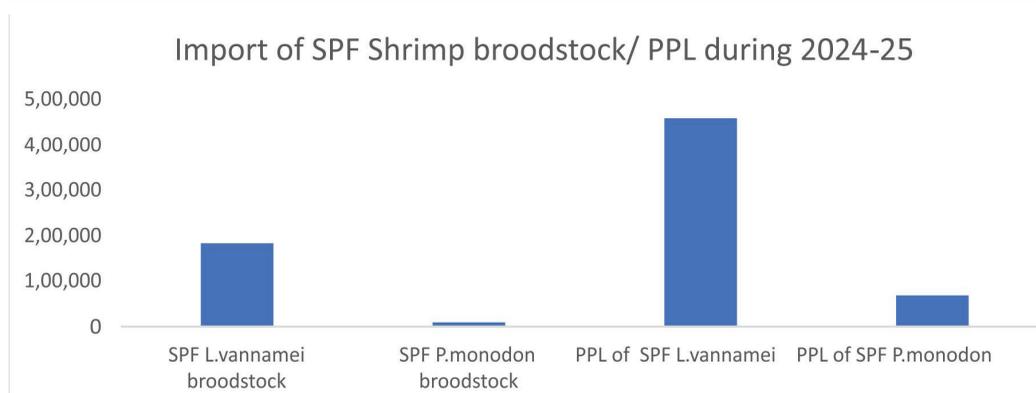
Antibiotic usage in aquaculture farms and hatchery operations is one of the major threats to the coastal aquaculture industry, resulting in the rejection of farmed shrimp consignments by importing countries. To regulate the misuse/abuse of antibiotics in coastal aquaculture activities, the CAA has banned 20 pharmacologically active substances and antimicrobial agents as prescribed in the CAA Rules and Guidelines. So far, the CAA has issued Certificates of Compliance to 9,120 antibiotic-free aquaculture inputs under ten categories (adult feeds, larval feeds, probiotics, feed additives, mineral mixtures, disinfectants, chemicals, immune stimulants, drugs, and others).



IV. Empanelment of SPF Broodstock Suppliers

The CAA has empanelled 14 overseas suppliers for the supply of SPF *L. vannamei* broodstock and PPL and 2 suppliers for the supply of SPF *P. monodon* broodstock, to facilitate CAA-registered hatcheries and BMCs for importing SPF shrimp broodstock and PPL into India. The CAA is also technically monitoring the activities of the Aquatic Quarantine Facility (AQF) located at Neelankarai, Chennai, which is operated by MPEDA-RGCA. The import of SPF shrimp broodstock and PPL during the year 2024-25 is furnished in the below table.

Import of SPF Shrimp broodstock/ PPL during 2024-25	Numbers
SPF <i>L.vannamei</i> broodstock	1,83,266
SPF <i>P.monodon</i> broodstock	9289
PPL of SPF <i>L.vannamei</i>	4,58,208
PPL of SPF <i>P.monodon</i>	68,568



V. Surveillance and Environmental Monitoring

Environmental monitoring is one of the major objectives of the CAA to ensure that coastal aquaculture does not cause harm to the environment and that farmed produce in the country is safe and meets international standards. CAA field staff are working closely with MPEDA-NaCSA and Fisheries officers and regularly inspecting hatcheries and collecting seed samples under the National Residual Control Programme for testing antibiotic residues. The CAA take action if samples tested for positive for antibiotic residues. Field staff are also collecting water samples from discharge points of the coastal aquaculture farms and hatcheries in coastal states and analysing them in government/university laboratories for water quality monitoring.

VI. Outreach Activities

The CAA is regularly organising sensitisation and awareness programmes on the CAA statutory provisions, adoption of good aquaculture practices, registration of coastal aquaculture farms and hatcheries, certification of aquaculture inputs, containment of antimicrobial resistance etc., These programmes targets the Member Conveners of SDLs and DLCs, farmers, hatchery operators and other stakeholders.

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4. The Coastal Aquaculture Authority Rules, 2024 , Notification issued on 9th January, 2024.

SHRIMP FARMING IN INDIA - THE PRESENT STATUS AND PROSPECTS

C. P. Balasubramanian, P.S. Shyne Anand, R. Aravind,
A. Panigrahi and M.Kumaran

Introduction

Shrimp is the most successful species contributing for the blue revolution and shrimp farming is one of the few remarkable success stories of modern aquaculture. Aggregate production of shrimp is showing an upward trend in India as in other shrimp farming countries, for example: the estimated farmed shrimp production in India during 2022-23 was about 0.9 million tonnes. This impressive growth in production of the farmed shrimp attained during the last few decades does not mean that the industry is without problems. The aquaculture of shrimp is severely impacted by frequent disease outbreak, issues in production and marketing, however, it is still among the most successful aquaculture crops. In this chapter, we attempt to provide an account on how shrimp farming evolved in India, the present status production, issues and way forward.

Shrimp aquaculture: subsistence to commercial farming

History of shrimp farming in India is almost similar to the other South East Asian countries. In the early 1920s, juvenile shrimps were extensively fished from the paddy fields bordering the backwaters and estuaries of Kerala (pokkali), West Bengal (bheries), Karanataka (Ghazan) and Goa (Kazhan), and were exported as a shrimp product known as 'prawn-pulp'. Later due to the innovation in the preservation techniques in India, the demand for larger shrimps has increased considerably, and, therefore it was essential to grow the shrimp in the farm field to meet the demand of export industry. Thus, the paddy field shrimp fishery has been evolved into a primitive form of aquaculture where, the naturally immigrating shrimp seeds from coastal waters are entrapped and prevented from returning to sea, and reared for few months, without any feed or aeration. Later, to augment the production, farmers started the practice of stocking the ponds with wild caught seeds and thereafter, when commercial hatcheries started, with hatchery reared seeds were stocked. This form of improved extensive type of shrimp culture is still prevailing in Kerala with a production of about 400 kg/ha to 1000 kg/ha for a short period of culture without supplementary feeding, where it can be understood that this type of culture is a form of ecosystem based culture or an organic shrimp aquaculture, in perennial farms and pokkali rice farming fields.

Although shrimp farming has been prevailing in coastal states of India for several decades, the commercialization really began to intensify in the early 1990s, after the successful demonstration of commercial tiger shrimp hatchery in Andhra Pradesh, through an MPEDA and DBT project, by Andhra Pradesh Shrimp Seed Production and Research Centre (TASPARC). The first recorded data on farmed shrimp production in India were 20 Metric Tonnes (MT) in 1970 and the first major change became obvious in 1990 when it reached 35580 MT. Farmed shrimp production showed a remarkable growth during early 1990s, and it has grown from almost 35000 in 1990-91 to 83,600 MT in 1998-99 with a 135% increase.

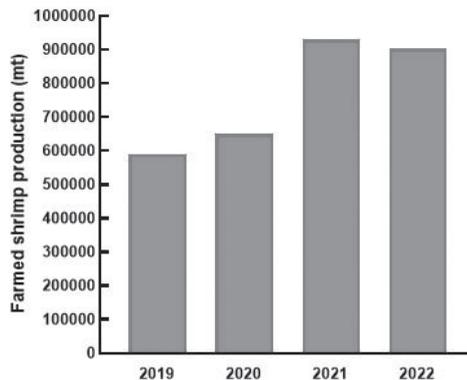
Shrimp aquaculture in India has faced several challenges after the first white spot panzootic in mid 1990s. Although WSSV was detected in 1993 itself, the largescale crop failure occurred after 1995. This large-scale production failure, however, did not reduce the estimated total production, possibly, due to the increase in the total area under culture. One of the most striking events in Indian shrimp farming scenario happened when Supreme court of India has made a verdict in 1996 to ban all nontraditional shrimp farming in the coastal zone of India. Subsequently, Govt. of India passed the Coastal Aquaculture Authority Act in 2005 to provide the regulatory frame work for carrying out shrimp aquaculture adhering to the principles of sustainable aquaculture. To facilitate the act, Coastal Aquaculture Authority (CAA) was established in 2006 for regulating the activities connected with coastal aquaculture in the coastal areas.

Introduction of Pacific White Shrimp (*Penaeus vannamei*)

Diseases have been the major constraint of shrimp farming in India since 1995. it was almost acknowledged that the seed stock raised from the wild broodstock cannot sustain the production in the culture system, because most of the wild brood stocks were infected with several pathogen. The use of post larvae produced from the specific pathogen free (SPF) broodstocks along with strict biosecurity measures are the most effective management option to ensure successful crops. *P. vannamei* was introduced to several South East Asian countries including India. In India, from 2010, a dramatic growth of farmed shrimp production was recorded due to the introduction of *P. vannamei* shrimp, from one lakh MT in 2009 to almost 9 lakh MT in 2022. This was possible due to the competitive aquaculture traits of genetically improved SPF *P. vannamei*, such as: high survival rate, faster growth rate, tolerance to high stocking density, lower dietary requirements, more efficient utilization of plant protein in the formulated diet and stronger adaptability to low salinity. Also, the biological advantages such as column feeding habits, and ease of reproduction in captive condition, contributed for the successful growth of vannamei farming.

Present status of shrimp farming in India

According to the estimate of the industry farmed shrimp production in 2022-23 was 9,02,525 MT which is slightly lesser than the production of 2021-2022 (9,30,000 MT). However, the production was increasing from 2019 onwards (Fig.)



The state wise shrimp production data reported by the MPEDA for the year 2023-24 is given in the Table.

Shrimp Farming Area and Production in 2023-24 (Source: the MPEDA)

Sl. No	State	Penaeus vannamei		Penaeus monodon	
		Area in Ha	Production in Tonnes	Area in Ha	Production in tonnes
1	West Bengal	6470	37365	51650	24815
2	Odisha	8409	42637	252	462
3	Andhra Pradesh + Telengana	97193	932693	4517	31365
4	Tamil Nadu + Puducherry	9183	41200	68	199
5	Kerala	284	804	3034	1048
6	Karnataka	706	2015	405	2252
7	Goa	112	272	21	20
8	Maharashtra	850	1968	33	68
9	Gujarat	2768	18015	6406	27430
	Total	125975	1076969	66386	87689
Total (P. vannamei & P. monodon)		Area: 192361 ha		Production: 1164628 MT	

Among the coastal states, Andhra Pradesh produced almost 82% of total production followed by West Bengal (5.3%), Odisha (3.7%), Tamil Nadu (3.5%) and Gujarat (2.6%).

Further, the region wise details of shrimp farming is briefly mentioned below.

Gujarat: Gujarat is the major contributor among the west coast shrimp producing states, and there was an increase in production when compared to 2021-22. This may be due to the farming of SPF tiger shrimp (*Penaeus monodon*). Occasional incidences of White Spot Viral disease and Microsporodiosis disease caused by EHP were reported in the vannamei farms. Maharashtra, Goa, Karnataka, and Kerala are the other shrimp farming states on the west coast with a total production of 7200 MT.

Tamil Nadu: There was a marginal increase in the production during 2023-24, however, only 60% of total farms were used for culture. Three major regions of shrimp farming in Tamil Nadu are: Region-1: Tiruvallur (ponneri), Chengalpet (Mahabalipuram), Villupuram (Marakkanam) districts; Region-2: Cuddalore, Mayiladuthurai and Nagapattinam districts; Region-3: Thiruvarur, Thanjavur, Pudukottai and Ramanathapuram districts.

Andhra Pradesh (AP): This state is categorized into four regions: South Andhra Pradesh, Krishna, West Godavari and North AP. There was a decrease in the production in all regions except south A P. South Andhra Pradesh covers Nellore, Prakasam and Guntur districts. The success rate is reported to be high in these districts. Some areas, particularly Kavali area had consistent high production due to the strict adherence of crop holidays during Feb to May months every year. During the year 2022-23, this region had a marginal rise in the farmed shrimp production while all other regions showed decrease in the production. In Krishna district most farms are at low saline regions, and were previously used for the fish culture. Shrimp is also produced in polyculture with fish here. West Godavari is the largest region in terms of farming area, and shrimp production reached as high as 270000 MT in 2021-22 and reduced to 240000 MT in 2022-23. The higher production in this area may be due to the expansion in farming area, reduced number of days in culture and rotation of crops from shrimp to fish during July to November. North AP includes East Godavari district and other northern districts. Many shrimp hatcheries are located in East Godavari district, and about 40% of shrimp seed (post larvae) are produced in this district.

Odisha: Here also slight increase in the production compared to 2021-22. Most of the existing shrimp farms operated during las year. About 8000 MT of shrimp is produced by the traditional shrimp farms of the state. This state is prone to natural calamities such as cyclone and storms.

West Bengal: The major shrimp farming state on the north-east coast, the production was dropped from 88000 in 2021-22 to 61825 mt in 2022-23.

Hatchery segment

According to the statistics published by Coastal Aquaculture Authority of India, a total of 462 registered *Penaeus vannamei* hatcheries are operating in India, and most of the hatcheries are located in Andhra Pradesh and Tamil Nadu. In 2023-24 shrimp post larvae production was reached an all-time high of about 100 billion. Additionally, six SPF *P. monodon* hatcheries are presently functioning in India. In 2024, around 2.8 lakh broodstocks of *P. vannamei* were imported.

Advances in shrimp farming systems

Shrimp aquaculture in India is not stuck in the status quo, and new interventions have been tried. Shrimp farming, particularly *P. vannamei* farming has been evolved from culture where larger ponds are stocked with low stocking density, which is prevailing in Ecuador, to a small pond with water recirculation, waste capture, environmental control and high stocking densities with strict biosecurity. In order to improve the production and better control over the production cycle, a two-phase culture system has been evolving: A nursery phase for 21 to 30 days that is followed by a grow out phase for 2 to 3 months. In shrimp farming, the nursery systems provide numerous benefits such as improved inventory, size uniformity, less predation, reduced pond grow-out duration, an increase in the number of harvests per year, better feed conversion efficiencies, greater biosecurity, compensatory growth during grow-out stages and higher grow out yields (20-30 % increase productivity compared to the traditional single-phase grow-out system).

Shrimp nursery systems

Several types of nursery rearing system have been developed with various levels of success.

- ❖ Clear water nursery systems
- ❖ Biofloc based nursery systems
- ❖ Recirculatory based nursery units
- ❖ Hybrid nursery systems
- ❖ HDPE lined pond nursery with well-prepared dyke

Among these Biofloc technology (BFT) is one of the novel strategies to augment the technical efficiency of shrimp farming. BFT needs a specific Carbon to Nitrogen ratio, and the heterotrophic bacteria produced through the BFT able to utilize nitrogenous waste metabolites and preserve the water quality. The produced flocs are used as additional nutritional sources. The production rate is high in the

biofloc system. Despite the benefits of the biofloc, it has limitations such as high aeration to suspend the particle in water column, high infrastructure and installation expenditure, greater energy consumption, high carbon foot print and complicated management protocol to suspend solids. An system popularly known as mixotrophic, the heterotrophic and microalgae are supplemented with organic carbon without specific C:N ratio.

ICAR-CIBA has developed a modified copefloc system to optimize the nursery rearing of penaeid shrimp. Copefloc is developed using filtered fermented juice of rice bran, molasses and yeast, and which is inoculated with copepod species. Nursery tanks are stocked with 12 day old post larvae *P. vannamei* PL at a rearing density 1000 to 10,000 PL/m³. Copefloc is added on alternate days, and 20% water is exchanged weekly. The salinity is maintained at 23 ppt. Fermented juice is added on weekly basis and copepod density is maintained at above 1000 no/L through-out the culture period. The amount of nursery feed required during the culture period was significantly less (20±1.1%) in copefloc system compare to the control. Copefloc reared *P. vannamei* showed compensatory growth with low feed conversion ratio in the grow-out culture ponds directs its importance in shrimp farming sector. Nursery rearing system can either developed out door at on farm site as well. However, indoor nursery system is more biosecure than the on-farm unit. HDPE lined on-farm units are used successfully by farmers in Andhra Pradesh.

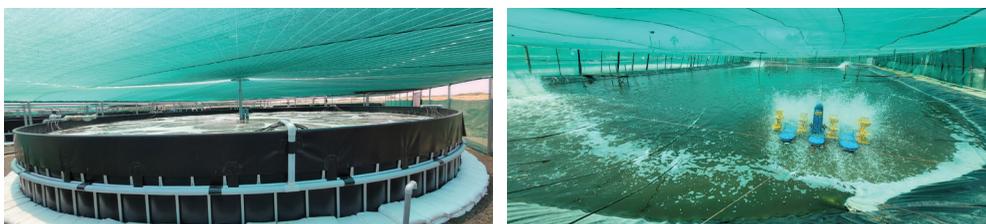


Fig. Tank and lined pond based shrimp nursery systems

Back to black tiger shrimp

Black tiger shrimp, *Penaeus monodon* was the dominant marine shrimp in India and in world markets. However, later in 1990s the culture of tiger shrimp began to fail. The reasons are frequent disease outbreak, harvest size became smaller and feed efficiency dropped, and eventually culture became non profitable. This failure of the black tiger shrimp farming opened the way for SPF *P. vannamei* from abroad. However, the last few years witnessed the rise in *P. monodon* farming due to the availability of SPF *P. monodon*. The resurgence of *P. monodon* is not only due to the new genetics but the species tolerates the microsporidiosis caused by the parasite *Enterocytozoon hepatopenaei* (EHP) and white feces syndrome(WFS) better than vannamei.

An experimental culture of SPF *P. monodon* was conducted by ICAR-CIBA in experimental station of CIBA at Navasari, Gujarat. SPF monodon was stocked at a rearing density 15/m² and culture for 105 days, and animals were fed with formulated feed of 38% protein. The animal reached a final average body weight of 29.5 g with a survival of 71%.

Shrimp culture in plastic lined ponds

In general, shrimp farming is carried out in coastal regions using the brackish water/ seawater. Many times the soil type may not be suitable for farming. For example, soil with seepage and low water holding capacity are not suitable for construction of ponds. Similarly acid sulfate soil will develop a low pH, which is unsuitable for shrimp growth and survival. Organic soil do allow stable embankments and have elevated oxygen demand. Further, these ponds are non-drainable and after few crops the culturing in these ponds will be difficult. Lining the ponds with plastic is one of the best method to alleviate these problems. Although the studies on pond lining have been carried out during the inception of shrimp farming, it is only in the last few years that this technology has been widely adopted in aquaculture. Both HDPE (high density polyethylene) and Poly Vinyl Chloride (PVC) are used for lining. This material can resist deterioration by UV light and stable for many years. The recommended thickness for a shrimp pond liner is at least 0.75 mm, and many suppliers of HDPE and PVC liners guarantee their product use under normal conditions for five to 10 years. Lined shrimp ponds that are well-designed, built and managed can efficiently manage organic matter and sludge with a central drain.

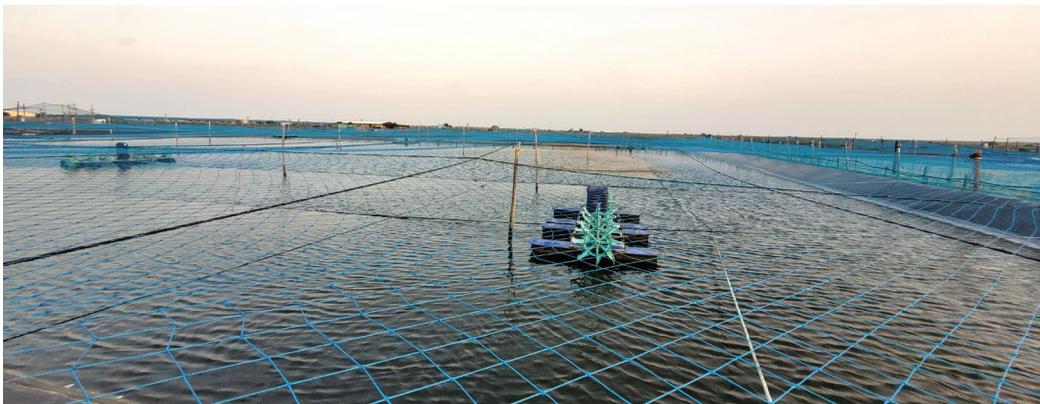


Fig. HDPE lined shrimp pond

Advantages

- ❖ Lined ponds prevent contact with acid-sulfate soils to avoid low pH in pond bottoms and water, which normally would create problems in shrimp ponds, especially during the rainy seasons.
- ❖ Pond water quality is more easily managed because there are no negative effects on pond water quality from contact with bottom and dike soils. Liners effectively prevent soil-water interaction and prevent the issue of soil acidity, stop salinization of neighboring areas, and control seepage of water into the ponds in areas with a high water table.
- ❖ Liners shorten pond cleaning and preparation time, requiring only four to eight days to complete the process compared with 30 to 45 days for the normal earthen pond cleaning and extensive drying process. Therefore, the number of crops per year can be increased to make annual pond productivity higher.
- ❖ In addition, harvesting can be more effective during the rainy season because plastic-lined ponds can still be cleaned. And no tractor earth work is required after the liners have been installed.
- ❖ During the culture period, suspended solids and other waste can easily be removed by gravity flow through drains (typically in the center of the pond), so that less organic matter will accumulate in the ponds.
- ❖ Liners prevent the erosion of dikes and levees from waves, wind, and aerator-generated water currents, which reduces pond maintenance and repair expenses. And lined ponds can generally be aerated more intensively, supporting higher stocking densities and yields per unit area.
- ❖ Because the pond bottom is cleaner, the quality of the shrimp is good and cleaner shrimp will command better prices.
- ❖ More importantly, lined ponds can easily be managed to prevent diseases like EHP.

Disadvantages

- ❖ High cost of liner material
- ❖ Difficulty in initiating the plankton bloom
- ❖ Once culture starts phosphorus accumulates and more often plankton bloom occurs. This can cause low night time dissolved oxygen levels and plankton die-offs, which can also cause dissolved oxygen deficiencies. Therefore, more mechanical aeration may be required in lined ponds than in those ponds without liner, especially during the second half of the culture period.

Pre-stocking management measures in shrimp farming

The success of any shrimp culture depends to some extent on the better management practices involved in pond preparation and pre-stocking management steps. Pond preparation is one of the most important pre-stocking management measures essential for optimum growth of shrimp in grow-out farming systems. There are various points to be taken care of during the pond preparation for shrimp culture.

1. Deepening of ponds

Pacific white shrimp *P.vannamei* lives in the water column and it is being cultured in higher stocking densities up to 60 PL/m². Hence it requires deep ponds up to 2 meters with 1.5 to 1.8 meter water column to hold the biomass.

2. Strengthening of pond dykes

P.vannamei shrimp is stocked in higher densities and to keep the dissolved oxygen at a required level and keep the pond water in motion to bring the sludge towards the center of the pond it requires higher level of aeration @ 1 HP per 300 Kg of biomass constantly. Continuous aeration might cause erosion of bunds which led to water turbidity which is harmful to the shrimp. Hence, as a preventive measure adequate compaction of the dykes with cement slabs or sandbags or High Density Poly Ethylene (HDPE) sheets is essential. Moreover, the lining of dykes HDPE sheets minimizes the dyke erosion and keeps them intact.

3. Central drainage for sludge removal

Large quantities of inputs like feed, minerals and probiotics are applied in shrimp ponds. The uneaten feed, fecal matter, suspended solids, dead organisms and planktons are accumulated in larger quantities as sludge. This sludge has to be removed periodically may be once in a week to minimise the organic load in the pond water and bottom metabolites like ammonia and hydrogen sulphide which could cause stress to the animal with deteriorated water quality. Hence, laying a central drainage system using PVC pipes from the central portion towards the sluice will help in removing the accumulated sludge and maintain the pond water quality. Sludge pumps can also be used to draw out this sludge periodically.

4. Biosecurity

As per the CAA guidelines the registered hatcheries have to import SPF broodstock from the identified suppliers and supply SPF seeds to the farming community. Specific Pathogen Free (SPF) shrimp means that the animals have been

assured of being free from specific pathogens at a particular point of time. It is a wrong belief that SPF animals are resistant to and cannot be infected by any viral pathogens that shrimp encounter during culture. Once the animals are removed from the SPF production facilities, they are no longer referred to as SPF, even though they may remain pathogen free. Once outside the SPF facility, the shrimp may be designated as High Health (HH) as they are now subject to a greater risk of infection, but only if they are placed into a well-established facility with biosecurity protocols. If the shrimp are put anywhere else, for example into a non-biosecure maturation unit, hatchery or farm, they can no longer be called SPF or HH as they are now exposed to a high risk of infection. Even the SPF seed once stocked in the pond is prone to pathogens from the pond environment or vectors. Therefore, adequate biosecurity measures like having reservoir, filtrations, disinfection of initial pond water, reservoir waters, disinfection of farm tools, hand and foot dips, fences, restriction of visitors and farm gates are very essential to prevent the entry and spread of pathogens in the culture system.

5. Waste water treatment pond (WWTP)

Most of the farms adopt zero water exchange systems. The drainage water released after final harvesting contains high load of organic matter and metabolites. This wastewater has to be sent through stabilization and treatment ponds to remove the suspended/dissolved solids and treated in the treatment pond with bleaching powder to remove harmful substances. The drainage water should not be released without de-chlorination. Release of drainage without treatment might lead to eutrophication of creeks, low DO, higher Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) which would affect the biological community structure in the receiving water bodies. Further, secondary aquaculture of finfishes, seaweed and bivalves in the DTP would aid in biological amelioration (*in situ*) of the wastewater and additional income. A wastewater treatment pond is very essential. The Coastal Aquaculture Authority permitted joint WWTPs by a group of small farms located as clusters.

6. Pond drying

After the final harvest of a crop sun drying of pond bottom for 3-4 weeks is essential till it cracks or loses its moisture content. Drying and cracking of pond bottom helps in microbial decomposition of soil organic matter and mineralization of organic nutrients (nitrogen and phosphorus). It was reported that if the previous culture was affected with white spot disease, the disease causing pathogen (WSSV) or its carrier could be present in the soil for 19-21 days in drainable ponds and in case of non-drainable ponds the virus remained infective for 35 days. In such cases 5-6

weeks of drying is recommended to eradicate the pathogens. Moreover, screening of pond sediment is also essential for the presence of viral pathogens in such ponds.

In the case of completely non-drainable ponds the accumulated black soil in the pond bottom is to be flushed in the form of thin slurry using a sludge pump. Organic biodegradable piscicides like Mahua Oil Cake (100-150 ppm) or Tea Seed Cake (15-20 ppm) or chlorine @ 20 ppm can be used for the elimination of unwanted organisms. Formalin or potassium permanganate or povidone iodine can also be used to kill the bacteria and external parasites as these compounds are degradable within the system and do not cause water pollution. Similarly, quick lime (calcium oxide (CaO) is recommended for enhancing the oxidation of organic matter and also as disinfectant.

7. Scrapping and sludge removal

Organic wastes in the form of a black layer at the pond bottom is formed due to the accumulation of decayed uneaten feed, dead and decaying plankton/algae and fecal matter of shrimp during the culture. This type of waste material releases toxic organic metabolites like ammonia and hydrogen sulfide in to the pond water and causes stress or death to the shrimp. Therefore, this black soil layer to a level of 5-10 cm depth should be scrapped and dumped away from the farm. If a farmer does not remove the black soil and start the next crop the possibility of having higher toxic metabolites at the pond bottom remains very high which affects the pond environment and cause stress to the shrimp.

8. Ploughing

Ploughing of the pond bottom exposes the black soil underneath the pond bottom to sunlight and atmospheric oxygen. Tilling of bottom soils enhances drying to increase aeration and accelerate organic matter decomposition. The depth of tillage should be 5 to 10 cm. By this the organic wastes in the pond bottom get oxidized and made available as nutrients. Presence of moisture in soil during ploughing allows bacteria to work better in breaking down the black organic matter, thus making the ploughing process more effective. Ploughing before liming is more useful and tilling after liming could enhance the soil pH. It was reported that ploughing the bottom soil with cultivator first and then with rotavator provided better oxidation to soil and enhance the availability of nutrients, release of obnoxious gases and better decomposition. Rotavator makes smaller lumps of soil which provides better oxidation and minimizes seepage.

9. Monitoring soil parameters

The optimum soil parameters are given in the Table. The optimum soil pH is 7 wherein the availability of nutrients and micro nutrients are at maximum.

Table. The optimum soil parameters

Parameters	Optimum Range
pH	7.0-8.0
Organic carbon (%)	1.5-2.0
Available nitrogen (mg/100g)	50-70
Available phosphorus (mg/100g)	4-6
Calcium carbonate (%)	>5.0
Electrical conductivity (dS/m)	>4
Textural class	Sandy clay, sandy clay loam and clay loam

Liming of shrimp ponds is done to neutralize soil acidity, increase the total alkalinity and total hardness concentrations and enhance the primary food productivity in the pond water. When the soil pH is below 7 and the total alkalinity is less than 60 ppm then it requires liming. Agricultural limestone (CaCO_3) is the safe product. Extra care is required if lime is applied in the form of burnt lime (CaO) and hydrated lime (Ca(OH)_2). If they are excessively used the pH will dangerously go very high. Approximately to increase the pH by 0.1, we need to apply 50 kg of CaO or Ca(OH)_2 or 100 kg of CaCO_3 . If the soil pH is more than 7 and the total alkalinity more than 60 ppm application of lime is not required. In case of slight adjustment of pH during pre-stocking preparations, dolomite which is calcium and magnesium carbonate can be used which help in plankton development. In low saline waters liming can improve phosphorus availability and enhance the pond productivity. Liming accelerate the microbial activity, diminish the accumulation of organic matter and enhances the availability of nutrients. Liming improves the hygiene of pond bottom.

10. Disinfection

Direct use of creek or sea water is risky as it may introduce pathogens. Disinfection of initial water taken to the pond is essential to kill the unwanted organisms, pathogens and their hosts. Otherwise there is every chance that vectors of pathogens could enter in to the water. Generally 20-30 ppm chlorine (200-300kg of bleaching powder/ha) is used as no microbes or its hosts could survive in this dose of chlorination. However ascertaining the organic load in the source water (chlorine demand) and chlorine percentage in the bleaching powder would be the better

indicators to decide the chlorination dose. Disinfection of pond water with bleaching powder will not affect the efficiency (availability) of minerals present in the water.

11. Aging of pond water

The white spot virus can survive as free living form in water up to 12 days. Aging of pond water during initial water culture after chlorination and de-chlorination will help in removing them. The permissible level of chlorine residuals in the disinfected should be less than 0.001 ppm. After 12 days, addition of the fermented juice is beneficial due to enhanced bacterial growth in adequate quantity and has abundant primary productivity.

12. Development of natural food/primary productivity

Application of fermented organic juice for the development of phytoplankton and stabilize the pH is reported to be effective. In the case of low saline water cultures, external supplementation of minerals needs to be done to keep the optimum mineral requirements. In order to mix these inputs uniformly throughout the pond gentle aeration is required with paddle wheel aerators. The application of fermented juice acted as carbon source for multiplication of beneficial bacteria in the pond and the bacteria require protein for its metabolic activity, the protein is synthesized by using the ammoniacal nitrogen present in the pond water. Thereby it reduces the ammonia level in the pond and improves water quality. Further, the fermented juice helps in stabilizing the pH to the desired level and promotes the development of plankton food. Application of fertilizers is mostly done in low saline vannamei culture. Nitrogenous fertilizers like Ammonium chloride/Ammonium sulphate are being applied to provide nitrogen for better phytoplankton production. The compound fertilizers like Di-ammonium phosphate (DAP) will provide both nitrogen and phosphorous required for the bloom development. The Murate of Potash (MOP) as a mineral nutrient enhances the potassium content in the low saline waters. Dolomite which is calcium magnesium carbonate promotes plankton growth and help in photosynthesis of planktons.

13. Application of probiotics

Probiotics could help in regulating the micro flora of the pond water, control pathogenic microorganisms, enhance the decomposition of undesirable organic substances and improve the pond environment. Application of plankton promoters enhances the availability of nitrates and phosphorus which are important for the planktonic growth. The beneficial bacterial strains inhibit the pathogenic bacteria and help in better survival. In case of low saline water shrimp culture, the pond water has low level of essential minerals like calcium, magnesium, sodium and potassium

which might cause stress to the larvae by disturbing the osmo-ionic balance of the shrimp larvae. Beneficial bacteria are helpful in nutrient recycling and organic matter degradation and thus keep the pond environment clean. Therefore, application of probiotics and minerals can help in enhancing the primary productivity.

14. Selection of quality seed

The seeds produced from the Specific pathogen free (SPF) *L. vannamei* shrimp brood stock are known as SPF vannamei seed. These SPF broodstock are developed under rigorous quarantine and screening of pathogens over several generations from the SPF mother/founder broodstock. This does not, however, guarantee against the animal being infected with unknown pathogens or known pathogens which are not screened against during SPF programme. The standards for vannamei shrimp seed quality are given in the Table.

Table: *P.vannamei* shrimp seed quality parameters

S.No	Parameter	Standard
1	Colour	light to dark brown
2	Activity	Very active
3	Feeding behaviour	Readily accept and eat feeds
4	Gut	Full gut and with a tail muscle to hind gut ratio (MGR) of 4:1 or more
5	Hepatopancreas	Developed in at least 90% of the sample given and full with oil globules.
6	Rostral spines	More than 5 should be observed
7	Body Length	12 mm and above
8	Size variation	Less than 10%
9	Appendages	Intact without any deformity
10	PCR screening for viral and bacterial diseases	Negative
11	Pigmentation	Chromatophores well defined and located along the mid-ventral line
12	Stress test with survival	100% for salinity reduction and above 90% for formalin test.
13	PL stage	PL 12 and above. Adequate gill development will not be there in small size PL.
14	WSSV/EHP	Absent based on Real time PCR - two step nested PCR.
15	Necrosis	Absent
16	Fouling	Clean without any fouling organism

The farmers must insist on screening of seeds and adopt quality-checking measures as they did in tiger shrimp. The following procedures need to be done to ensure the selection of quality seed.

- ❖ *Physical stress test:* Collect a larval sample (approximately 500 PLs) from the bottom of the identified larval tank, put them in a tub and rotate the water. If many seeds are concentrated in the center of the tub reject the tank.
- ❖ *Salinity stress test:* Collect about 100 PL in a beaker with a tank having the optimum salinity. Pour an equal quantity of freshwater and wait for half an hour. If you find any mortality reject that tank.
- ❖ *Formalin stress test:* Collect 100 PL of vannamei shrimp seed from the selected tank and put them in 100 ppm formalin water and wait for an hour. If more than 90% of the seed survives then select that batch.
- ❖ The seed selected should be from a single spawning and should be from the first or second time spawning of the specified mother brooder. Seeds from mixed spawning lead to low survival and size variation.
- ❖ Seed should be PCR screened for known pathogens (WSSV, EHP, etc.) before selection. PCR test is available for IHHNV, MBV, HPV, TSV, YHV (Viruses) and for many of the vibrio.
- ❖ After selecting the seed lot it should be gradually acclimatized (3 to 4 salinity in a day) to the pond water salinity. Rapid acclimatization leads to stress and low survival in the farm.
- ❖ Farmers from a shrimp cluster should procure seeds collectively through their association from a reputed and trusted hatchery. Farmers should stay in the hatchery to closely monitor the seed production process. PCR screening of the mother brooder before and after spawning will ensure the pathogenicity of the brooder.
- ❖ Further post larvae are transported in the polyethylene bags, which is kept in the styrofoam box. The temperature of the water is artificially reduced by keeping ice box in between the polyethylene bag. Therefore, the temperature of the transportation bag is far less than pond water. In general, farmers float the bags in the pond for 30 minutes to 1 hour.
- ❖ Stocking density should be decided based on the carrying capacity of the pond.
- ❖ The CAA has permitted a maximum density of 60 PL/m² provided the farm has adequate infrastructure and biosecurity. Carrying capacity is the optimal biomass (tonnes of shrimp/ha) holding capacity of the pond. It is dependent on many factors like biosecurity, electricity, aeration,

water quality, quality of inputs, practices followed, experience, technical and management capacity of the individual farmer and other extraneous factors. Based on the experience, a farmer should decide the optimum stocking density for the pond within the permitted level.

Issues and way forward

The major issue in the present-day shrimp farming is the sale price has become reduced due to the over production. All Asian countries have been facing the same problems and issues. Shrimp has a short production cycle which makes it easy to move in and out of production. But this is only a short-term solution. The long-term solution is to increase the production efficiency. There are opportunities such as domestic marketing, and supply of different products such as ready to eat, ready to heat and ready to cook products. Thus, product diversification is one of the strategies to make shrimp farm more profitable. The move to production of black tiger shrimp is an another opportunity.

Some of the other strategies to increase the production efficiency are:

- ❖ Reduce the crop length
- ❖ Lower stocking densities
- ❖ Modification in the infrastructure: for example pond lining, to prevent EHP
- ❖ Better water treatment
- ❖ Addition of nursery system
- ❖ Break between the crop and pond preparation
- ❖ Area specific crop holidays
- ❖ Shrimp polyculture
- ❖ System diversification

The strength of the industry can often be measured by the investments and growth. Innovation should drive in the more efficient nursery rearing system, alternative feed ingredients, green energy and more efficient RAS system. In order to move forward we need to focus on predictability and efficiency.

FEED MANAGEMENT IN SHRIMP AQUACULTURE

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Introduction

Feed represents the largest variable cost in shrimp aquaculture and is the single most factor influencing the growth of shrimp as well as pond water quality and contributes directly for the improved profitability of shrimp aquaculture. Feed management can be defined as the control and use of feed for aquaculture operation in such a manner that the utilization of feed is optimum with minimum wastage, negligible impact on environment, achieving best feed conversion ratio (FCR), better soil & water quality, maximum growth of shrimp and production. Here it is to be kept in mind that a best feed can produce poor results if the feed management is poor. Alternatively, a moderate feed can produce best results under good feed management and hence feed management assumes considerable significance. Feed management starts from the procurement and ends with the best use of the feed for a good harvest on the final day of shrimp culture. The BMPs in feed management required to be followed by farmers for successful shrimp culture are given below.

How to select a quality shrimp feed ?

A quality feed in common parlance is that the ability of the feed to give good growth and FCR without affecting the shrimp health and pond water quality. Hence, the quality is comprised of the physical, nutritional and biological quality of the feed. The first and foremost point farmers looking up to select the feed is its physical quality.

Physical quality

The feed pellets should be of uniform size and appearance, physical integrity and without any fine dust/powder. The feed should be fresh with good fishy odour and presence of too much or too less odour is not ideal. There should not be any clumps and visible fungus. The physical integrity and nutrient leaching are of high importance in shrimp feed quality because of not only financial loss due to the loss of nutrient but also the implications it will have on environment. Farmers are evaluating the physical stability of the feed pellets to retain its physical integrity without nutrient leaching and disintegration. The feed should absorb minimal water so that it can become soft for ease of consumption.

Chemical quality

The feed to be selected should match the nutritional requirements of shrimp. Though most of the feed manufacturers are giving the nutritional composition the farmers should verify the composition by analyzing its nutrient composition. The feed should be free from antibiotics and banned chemicals.

Biological quality

The feed should be attractable and palatable to the shrimp and there should not be any problem in intake. It should be highly digestible with negligible waste generation resulting in good growth and better FCR. Further, it should maintain the pond water quality within optimal parameters.

Feed storage

Feed storage is also an important component of feed management. On receipt of feed batch, all the feed bags should be weighed and examined for physical damage, opened or broken signs including the signs of repacking. The date of manufacture and the expiry should be ascertained and the points to be considered for storage are:

- ❖ Feed should be stored in a dry, cool well-ventilated area
- ❖ Shrimp feed should be stacked to a maximum of 10 bags per stack
- ❖ Direct storage on the floor should be avoided and preferably 1 to 2 feet away from the walls and over the pallet
- ❖ Do not trample on the bags
- ❖ Once opened it should be consumed at the earliest
- ❖ Always use the policy of first in, first out so that there are no old stocks are cleared
- ❖ Too much handling has to be avoided as it increases the fine dust in the feed bags
- ❖ The storage area should be insect and rodent proof



Fig. Proper storage of shrimp feed on the pallets over the floor

Feed management during first 30 days of culture

The feeding is proportional to the body mass in all living animals including shrimp. However during the first 30 days of culture ascertaining the actual standing biomass is difficult. Hence the concept of blind feeding is practiced. This is based on the assumption of approximate survival and bodyweight. To start with approximately 100% of the body weight and at the end of thirty days it will be gradually reduced to 8-6%. However, for ease of understanding and use all the feed manufacturers are recommending a feeding guide based on their experience and assumptions. The total quantity of feed offered during the first 30 days are less than 10% of the total feed used in the culture and hence there will not be any problem during the blind feeding period even if the feed given is little more than the requirement.

During this period feeding has to be done along the dikes as the post larvae are having the tendency to move along the sides of the pond dykes. The feed used during this period will be in the form of crumbles and the chances of feed crumbles blown out of the pond due to the wind speed is high and also the feed has the chance for floating due to the lower density of the crumbles. Hence it is advisable to mix the feed with 10 to 15% of the pond water and then broadcast so that the feed will be broadcasted into the pond and facilitates immediate sinking.



Fig. Feeding along the pond dykes during the initial days of culture



Fig. Boat feeding throughout the pond after 30 days of culture

Feeding from 30 days to the harvest

From 31 days onwards feeding assumes much more significance and the actual requirement has to be ascertained by calculating the standing biomass as well as the average body weight of the shrimp. The sampling has to be carried out at 10 days interval and the biomass and average body weight has to be estimated to calculate the feed requirement. By sampling through 4 to 5 times cast netting the approximate survival, number of animals present, the average body weight are calculated and then the feed requirement per day is calculated as follows

$$\text{Feed required per day (10\%)} = \frac{ABW \times \text{No. of animals}}{1000} \times \frac{10}{100} \text{ kg}$$

The calculated quantity is divided into four meals and fed four times a day. Though more number of feeding frequencies is advantageous, considering the practical difficulties a feeding frequency of 4 to 5 is advisable. The recommended feeding time is 6AM, 10AM, 2PM and 6PM and will depend on the temperature. If the morning temperature is too cold during winter period the feeding can be delayed by 30 - 45 minutes. During the hot summer period the 2PM and 6PM feeding can be delayed by an hour.

From 30th day onwards check tray monitoring has to be compulsorily followed. Preferably four check trays are to be placed per hectare and feeding has to be adjusted based on check tray observation. To begin with 0.5% of the feed offered at a particular feeding time is calculated and kept in the check trays and observed at the end of two hours and thirty minutes. As the culture increases the % of feed offered increases and it reaches a maximum of 1% when the shrimps reaches the harvest stage (25g). The check tray monitoring time has to be gradually decreased from two hours 30minutes during 30 to 60 days to one hour 30 minutes at the end of the culture. The quantity of feed required for the next meal should necessarily be based on the check tray monitoring and the following guidelines are to be followed in deciding the feed requirement based on the check tray observation.



Fig. Check tray observation for the feed consumption and monitoring the animal health and growth

Quantity of leftover feed at the prescribed time	Change in feed quantity
No pellets remaining	Next meal can be increased by 5.0%
Fewer pellets to upto 5% of the feed remaining	No change and keep the same quantity for the next meal
5 to 10% of the feed remaining	5% decrease in quantity of the meal for the next time
10 to 20% of the feed remaining	10% decrease in quantity of the meal for the next time
20 to 30% of the feed remaining	20-30% decrease in quantity of the meal for the next time
More than 30% of feed remaining	Stop feeding for the next meal and start feeding again but decrease the quantity by 50% and increase to normal when the total feed is consumed

All the feed manufacturers use to give the feeding chart but farmers has to keep in mind that these are just guidelines only and not the final one. Actual feeding will vary from pond to pond and so many factors are contributing for the feed intake y. Feed has to be adjusted on actual consumption basis and will vary based on growth, moulting cycle, stocking density, natural productivity, soil and weather quality and prevailing atmospheric conditions. A farmer is the best judge as he knows the scenario in his pond better and the feeding has to be in line with check tray monitoring only.

P. vannamei being amenable for higher stocking densities the feed requirement per time sometime increases beyond the manageable level of the feed boy and proper feeding is doubtful. The use of auto feeders are advantageous and the beneficial effect of auto feeders are not only reducing the labour requirement but helps in improving the growth, FCR and soil and water quality. A clear reduction of FCR upto a tune of 0.1 to 0.15 has been demonstrated through use of auto feeders. The increased feeding frequency and the constantly moving nature of *vannamei* resulted in the beneficial effect of feeding through auto feeders. In general, one auto feeder is sufficient per pond with water spread area of upto 1 hectare. By following the above BMPs in feed management farmers can improve their profitability.

WATER QUALITY MANAGEMENT IN SHRIMP AQUACULTURE

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Introduction

Water quality is indeed one of the most significant and challenging factors for successful shrimp farming. Shrimp is highly sensitive to changes in their aquatic environment, and maintaining appropriate water quality is crucial for their growth, survival, and overall health. A reliable, good quality and adequate water source is one of the prime requirements for continuous shrimp farming. Water with varying salinity can be used as a water source, provided the quality parameters are in the optimum level. Source water vary from seawater, saline groundwater of inland region, brackishwater from creeks, lakes, estuaries and sometimes freshwater. A number of water quality variables may affect shrimp farming, but, fortunately, only a few normally play a decisive role. Water quality variables such as salinity and temperature are important when assessing the suitability of a site for culture of particular species. Other properties such as alkalinity, turbidity, compounds of phosphorus, and nitrogen are vital because they affect natural productivity, which in turn, may influence shrimp production. Dissolved oxygen, carbon dioxide, ammonia, and other factors come to play during the grow-out period because they are potential stressors for the animal in culture. Maintenance of good water quality is essential for both survival and optimum growth of shrimp.

Source water treatment

Water treatment measures are necessary to create a favorable pond environment that promotes healthy shrimp growth and minimizes the risk of water quality issues throughout the culture. Source water of low turbidity can be directly disinfected using bleaching powder after filling the reservoir pond. Source water with high turbidity and organic matter is allowed to pass through a series of fine meshed netting for filtration of the water. Filtration of water with 60 μ filters prevents the entry of parasites and crustaceans that are carriers of diseases. Chlorination should be done in the reservoir pond to decontaminate the water by applying about 30 ppm chlorine. Chlorine dose varies with pH, concentrations of organic matter, microbial load and ammonia and the chlorine residuals should be less than 0.001 ppm before stocking. Intense aeration, addition of 1 mg L⁻¹ of sodium thiosulfate for every mg L⁻¹ of chlorine, and exposure to sunlight are some of the management practices to reduce chlorine residuals. In case of high clay turbidity with organic matter, the water is pumped into settlement pond wherein it stays for 2-3 days.

For source water with clay turbidity 300-500 NTU, poly aluminium chloride (PAC) is applied with a concentration of 3-7 ppm. To reduce organic matter, potassium permanganate is added at the concentration of 1-2 ppm.

Fertilization

In culture ponds, the water level is initially maintained to 30 - 40 cm and allowed to settle for a few days. By this time, the colour of the water may turn dark green with algal bloom and a layer of benthic algae along with associated food organisms will form at the bottom. Subsequently, small doses of organic (fermented rice bran or fermented organic juice) and inorganic fertilizers are applied based on the observations of algal production. The water level is then raised to 100-125 cm and the shrimp seeds are stocked after one week.

Management of water during culture

During culture, the parameters that should be monitored routinely are water temperature, salinity, pH, dissolved oxygen, total alkalinity, minerals, nutrients, and metabolites.

Water pH

Shrimp farming relies heavily on maintaining optimum water pH levels, which is one of the most critical parameters. The optimum level of pH is 7.5-8.5, and daily fluctuation of pH should be within a range of 0.5 differences. Dolomite could be used at the rate of 180-300 kg ha⁻¹ for 2-3 days to increase the pH when the pH difference in the afternoon exceeds 0.3. Agricultural lime could be used at the rate of 180-300 kg ha⁻¹ when the pH difference in the afternoon reaches 0.5. When the pH of the water exceeds 8.3, it could be decreased by water exchange, use of appropriate probiotics and fermented juice at the rate of 10-30 kg ha⁻¹. A comparison study between earthen and lined ponds indicated lower pH fluctuations in earthen than lined ponds as soil functions as a buffer against wide variations in pH. Another reason may be higher alkalinity in earthen pond (232-363 ppm as CaCO₃) than lined pond (196-298 ppm as CaCO₃).

Salinity

Salinity refers to the overall concentration of dissolved salts in water. Seawater is characterized by high concentrations of sodium and chloride ions, whereas freshwater typically exhibits higher levels of bicarbonate ions. Salinity determines osmotic relationships and also the growth, reproduction, metabolism, and migratory behaviour of the animal. Salinity range of 10 to 35 ppt with variations not exceeding 5 ppt is considered as an optimum level for growth and proper metabolic processes.

The optimum salinity requirement varies with the species. Among the shrimp species cultured in India, the Pacific white shrimp (*Litopenaeus vannamei*) is known for its remarkable osmoregulatory abilities, allowing it to thrive in a wide range of salinities. It can adapt and grow in environments with salinities ranging from 0 to 35 ppt and maintains its serum osmolality within a narrow range of 727-484 m Osm/kg against the wide range of medium osmolality (855-29) by retaining the essential ions through active transport by increasing the Na-K-ATPase enzyme activity.

Temperature

Pond water temperature significantly influences the metabolic, physiological activities and life processes of shrimp. As the temperature increases by 10°C, chemical and biological reaction rates double and the metabolic activity of organisms intensifies. This heightened metabolism leads to a higher oxygen demand, with aquatic animals requiring twice as much oxygen. It is crucial to maintain water temperature within the optimal range of 28 to 32 °C for shrimp farming and temperatures below and above the optimum range is known to weaken the immune status of the shrimp, making them more susceptible to diseases. No significant difference in temperature was observed between lined and earthen ponds and between surface and sub-surface water as water currents caused by mechanical aerators prevent the thermal stratification in shrimp ponds. The pond temperature varied during the culture period in accordance with the atmospheric temperature and was not influenced by the lining material.

Turbidity

Turbidity is an optical property of water that denotes the cloudiness or muddiness of water. Plankton-induced turbidity can be desirable as it signifies the presence of microscopic organisms that serve as a food source for aquatic organisms. On the other hand, turbidity caused by soil particles can negatively influence water quality. Plankton turbidity is measured in situ in terms of transparency using Secchi disc, and the optimum range is 25–50 cm. Higher transparency values (>60 cm) is indicative of poor plankton density, and the pond water should be fertilized with the right kind of fertilizers. A lower value (<20cm) indicates a high density of plankton, and hence fertilization rate and frequency should be reduced. Alum and ferric sulphate might be more effective as compared to hydrated lime and gypsum in removing turbidity due to clay. Simultaneous application of lime is recommended to maintain optimum range of pH while applying alum and gypsum, which tend to reduce pH and total alkalinity.

Dissolved Oxygen

Dissolved oxygen stands out as the most crucial water quality variable in shrimp culture. Photosynthesis plays a vital role in maintaining dissolved oxygen levels, as it serves as the primary source of oxygen in water. A thriving phytoplankton bloom is vital for sustaining adequate dissolved oxygen concentrations within a safe range. Adverse conditions such as heavy rain or lack of essential nutrients can lead to algal bloom, restricting the availability of dissolved oxygen to the animal. The optimum DO concentration is 4-10 ppm, where the toxic substances such as un-ionized NH_3 , hydrogen sulphide, and carbon metabolites are converted into their oxidized and less harmful forms. Depletion of DO in the pond can be controlled by water exchange and installation of aerators. Paddlewheel aerators are commonly used, which is capable of elevating the dissolved oxygen level from 0.05 to 4.9 mg L⁻¹ within 4 hours in a half-hectare pond. The latest aerators such as the long arm aerators and spiral aerators can circulate oxygen to the pond bottom more effectively. Generally, one horsepower of aerator is suggested for every 300 kg of biomass.

Minerals

Animals rely on minerals like sodium, potassium, calcium, and magnesium for their growth and metabolic processes. It is crucial to maintain a balanced ratio of these minerals in water, resembling the ratio found in seawater. Typically, water is considered suitable for shrimp culture if the mineral levels are similar to those found in seawater when adjusted for salinity. To calculate the desired mineral levels at different water salinities, the water salinity (in ppt) is to be multiplied by the factors shown for each mineral.

Minerals	Salinity		
	1 ppt	5 ppt	10 ppt
Calcium (ppm)	11.6	58.0	116.0
Magnesium (ppm)	39.1	195.5	391.0
Potassium (ppm)	10.7	53.5	107.0
Sodium (ppm)	304.5	1522.5	3045.0

The deficiency of mineral has to be corrected by the addition of calcium chloride, potassium chloride (Murate of potash), potassium magnesium sulphate (K Mag), hydrated magnesium sulphate (Epsom) as required. The salt to be added to the pond can be calculated based on the desired mineral level and the selected salt.

$$\text{Amount of salt to be added} = \frac{\text{Concentration of minerals required in the pond (in ppm)}}{\% \text{ of mineral ions in the selected salt}}$$

For example, to get the potassium content of 200 ppm, the amount of murate of potash to be applied = $200 / (50\% / 100) = 400 \text{ mg / l}$

Total alkalinity

Alkalinity is the water's ability to neutralize acid without changing the pH and is a measure of the total concentration of bases (bicarbonates, carbonates, phosphates, hydroxides) in pond water predominantly bicarbonate and carbonate. Alkalinity requirement varies with species and days of culture. *P.vannamei* requires more alkalinity than *P.monodon* by 20 ppm. Newly released shrimp requires 100-120 ppm whereas 45 and 90 days or older shrimp requires 120-150 and 150-200 ppm alkalinity respectively. Total alkalinity was found to be lower in lined ponds compared to earthen ponds and reduced significantly with days of culture. This reduction in alkalinity is not replenished by incoming water as there is no water exchange or from dissolution of carbonate minerals in pond bottoms as there is no soil in the lined pond. Alkalinity between 75 to 200 mg L⁻¹ is ideal in a shrimp pond. Application of dolomite, shell lime, and zeolite improves alkalinity and stabilizes pond water quality. Study showed that addition of NaHCO₃ highly effective compared to other chemicals. On the contrary, high total alkalinity (TA) is a major constraint faced by the farmers using borewell waters. Research work revealed that the addition of sodium bisulphate (NaHSO₄) is the best option to reduce TA and the requirement is between 1.3 and 1.6 ppm to reduce 1 ppm alkalinity.

Nutrients

Nitrogen and phosphorus along with carbon and other trace elements, serve as nutrients, thus accelerating the growth of phytoplankton, which is the base of the food web in the culture system. Phytoplankton density has a positive correlation with nitrate ($r=0.87$) and phosphate ($r=0.79$). Fertilizers are applied to increase nitrate and phosphate level (N:P = 15:30), stimulate phytoplankton growth and to prevent reducing conditions that lead to sulphide production in pond bottom soil. Phytoplankton communities may change depending on salinity levels and changes in nitrogen-to-phosphorus ratios.

Metabolites

The major metabolites in shrimp farming are ammonia, nitrite, and sulphide.

Ammonia

Ammonia is the by-product of metabolism by animals and bacterial decomposition of organic matter such as wasted food, faeces, dead plankton etc. Ammonia nitrogen occurs in two forms in water, un-ionized ammonia and ammonium ion. The fraction of ammonia depends on pH, temperature, and to a lesser extent on salinity. Un-ionized is considered a more toxic form of ammonia due to its ability to diffuse readily across the cell membrane, hence should be less than 0.1 ppm. The toxic effect may be minimized by 30-50% water exchange, reduction of pH and feed application, periodic partial removal of algal blooms by flushing or scooping out the scum and also maintaining a sufficient level of dissolved oxygen to oxidize ammonia to nitrate. The addition of liming agents such as hydrated lime or quick lime decreases ammonia, and this is effective only in ponds with low alkalinity. Supplementation of carbonaceous material increases the heterotrophic bacteria, which utilizes the nitrogen content in the pond for their multiplication, thereby reducing the ammonia concentration in the pond.

Nitrite

Nitrite is an intermediate product in the bacterial transformations of nitrogen in water. Nitrite concentrations are usually very low (< 0.1 mg NO₂-N/L) in shrimp ponds, it becomes still low during the summer (less than 0.05 mg NO₂-N/L) because the availability of substrate for nitrite production is limited by rapid rates of ammonia assimilation by phytoplankton. Nitrite toxicity increases with increasing pH and decreases with increasing calcium and chloride ions. The optimum level of nitrite is less than 0.2 mg/L and can be maintained by effective removal of organic waste, adequate aeration and correct application of fertilizer & feed, and use of biofertilizer for accelerated nitrification.

Hydrogen Sulfide

Under anaerobic condition, certain heterotrophic bacteria can use sulphate and other oxidised sulphur compounds in metabolism and excrete sulphide. Among the different forms of sulphur, un-ionized H₂S is toxic and is dependent on pH, temperature, and salinity and is mainly affected by pH. The build-up of H₂S is mostly in the sediments which are in highly reduced conditions (redox potential < 150 mv), low iron content, and the pH range of 6.5 – 8.5. The safe level of Hydrogen sulfide is less than 0.003 mg/L for *p. monodon* and the concentration of H₂S more than 0.01 mg/L may be lethal to aquatic organisms. Sulfide can be reduced by aeration, water

exchange, and circulation of water to minimize anaerobic zones in the pond bottom. Periodic pond draining and drying of bottom muds will result in the oxidation of sulfide and enhance the decomposition of organic matter. Anaerobic sulfur bacteria present in the reduced zones of sediment oxidizes H_2S into harmless HS and S forms.

Water quality management with reference to low saline shrimp culture

Farming of shrimp at low salinities has become common now around the world and most major producer countries have sizeable quantity of shrimp sourced from low saline shrimp farms. The very fundamental principle that lies behind the success of low saline shrimp culture is the euryhaline behavior of most commercially farmed penaeids and their ability to grow normally even at low salinities. There exists no clearcut definition for low saline shrimp farming and generally, the rearing of shrimp at salinities at or below 15 ppt is considered as low saline farming. *P. vannamei* is the species of choice around the world for low saline shrimp farming, given its remarkable ability to adapt to low salinities and grow optimally. It can be commercially grown at salinities varying from 2.5 to 50 ppt and reports of successful farming beyond this range is also common. The key components of low saline shrimp farming are ionic composition of low saline water, acclimatization of shrimp post larvae to low salinities, and challenges in low saline shrimp farming and its mitigation.

Ionic composition of low saline water

Ionic composition of the low saline water is a function of its origin i.e., seawater (seawater entering in to rivers as a result of tidal amplitude) or inland. The major ions that contribute to the salinity of the water are sodium, chloride, sulfate, calcium, magnesium, potassium, and bicarbonate. Among these ions, calcium, magnesium and potassium are considered the most important ions and the ratios between these ions are used to express the suitability of water for shrimp farming. Low saline water of seawater origin have ionic composition similar to seawater diluted to the same salinity and farming in these waters is relatively easy and without major challenges with appropriate BMPs. Saline groundwater of inland origin has a different ionic composition depending upon the parent rock and is different from seawater diluted to the same salinity.

The ionic ratios and the aqueous levels of the ions can be amended through supplementation of mineral salts such as muriate of potash (KCl), magnesium chloride ($MgCl_2 \cdot 6H_2O$) or magnesium sulphate ($MgSO_4 \cdot 7H_2O$) for potassium and magnesium supplementation respectively. Similarly, if the low saline water at any site is found to be deficient in calcium, it can be supplemented using anhydrous $CaCl_2$ or fused $CaCl_2 \cdot 2H_2O$. The recommended Mg/Ca ratio for low saline shrimp farming is 2:1 and the Na/K ratio can be maintained between 28:1 and 45:1. Maintaining is Ca/K ratio

close to 1 is also recommended for low saline shrimp farming. Saline groundwater of inland origin generally has greater total hardness levels than seawater of similar salinity due to disproportionately higher calcium and magnesium levels and is extremely deficient in K.

Acclimatization of shrimp post larvae (PL) to low salinities

Acclimatization of shrimp PL to low salinities is of prime importance for overall success of low saline shrimp farming. PL 6-8 days old should only be acclimatized to a salinity as low as 15 ppt. PL 10 -12 days old can be acclimatized to salinities lower than 10 ppt up to 4 ppt. For salinity acclimatization below 4.0 ppt it is always recommended to use PL 15 days old or higher. Most hatcheries would provide seed at low salinities as requested by the farmer. However, farmers shall make sure that post larvae of at least 10-12 days old are only procured for farming at salinities less than 10 ppt. For farms operating at salinities lower than 4 ppt, it is recommended to stock the seed in their own nursery and gradually acclimatize the animal. Salinity acclimation of seed produced in a hatchery at 28-32 ppt to the farm at low salinity is a very important step in the farming operations and improper acclimatization can result in mortality and loss of survival rates subsequently.

Challenges in low saline shrimp farming and its mitigation

P. vannamei can be reared at salinities as low as 1.0 ppt, although such farming would require very high skill levels backed by continuous analysis of ionic variables. Such a farming is also filled with uncertainties and mortality can quickly set in and sometimes tough to control. Hence it is always recommended to farm *P. vannamei* at salinities greater than 4-5 ppt to obtain the best results and such farming would encounter relatively lesser challenges with respect to aqueous ion levels and ratios. Most of the problems faced by low saline farmers are no different from issues faces by their counterparts in coastal regions i.e., diseases, running mortality, reduced growth, survival loss etc. Specific problems faced by low saline farmers are mostly a function of the ionic levels and ratios in the rearing medium. The major issues faced by low saline shrimp farmers due to issues with ionic levels are muscle/body cramping, white muscle, moulting issues, delayed recovery post moulting, reduced shell hardening etc. Some mitigation measures have been shown to improve the health status of the animal. In the case of white muscle in shrimp, application of potassium at 10-20 Kg/acre and its repetitions as required can effectively cure occurrence of white muscle in shrimp. Muscle cramping if not caused by sudden shock handling or temperature shock can be cured by application of potassium and magnesium salts and correction of Mg/Ca ratio in the rearing medium. Application of mineral mix to the pond water at regular intervals is necessary for farming below 15 ppt and the dosage will depend on the stocking density of the pond.

Conclusion

Water quality plays a pivotal role in achieving successful outcomes in shrimp farming. Water quality parameters need to be closely monitored at appropriate intervals by sampling at the right water depth viz., at sediment water interface and surface water. Timely identification of the issues and immediate mitigation measures using biological and chemical agents is key to protect the pond environment. Monitoring the pond conditions and preventing deleterious environmental buildup through better management practices are the key to beneficial economic outcome in shrimp farming.



Fig. Aeration through air blowers

SHRIMP DISEASES: PRESENT STATUS WITH SPECIAL REFERENCE TO HEPATOPANCREATIC MICROSPORIDIOSIS (HPM) AND WHITE FECAL SYNDROME (WFS) AND MITIGATIVE MEASURES

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Introduction

Shrimp aquaculture is a flourishing food-producing sector and is an important economic activity in many shrimp farming nations. The total global crustacean production was 9.2 million tonnes (MT) and contributed 23% to the total export value (FAO, 2022). Marine shrimps dominate crustacean production in coastal aquaculture. Among global crustacean production, the white leg shrimp, *Penaeus vannamei*, is the single species contributing the major share of 51.7%, with a production of 5.81 million tonnes (FAO, 2022). In India shrimp culture was started as a traditional practice in *bheries* and *pokkali* fields and transformed into commercial sector during early 1990. The total quantity of fish products exported from India during 2022-23 was 17,35,286 with a value of Indian rupees (INR) 63,969.14 crore, of which the frozen shrimp contributed a major share with a value of INR 43,135.58 crore. The three crustaceans *P. vannamei*, *P. monodon*, and *Machrobrachium rosenbergii* are the sole contributors to the Indian shrimp production of 8,43,633 tons. *Penaeus vannamei* is the dominant species. In India, 1,08,526 ha are under the culture of *P. vannamei*, and 58,196 ha are under the culture of *P. monodon*.

Diseases are the major constraint in shrimp aquaculture and its sustainability. The increasing trend in shrimp aquaculture commercialization has exacerbated the epizootics of diseases. Globally, viral diseases such as white spot syndrome virus (WSSV), monodon baculovirus (MBV), infectious hypodermal and hematopoietic necrosis virus (IHHNV), yellowhead virus (YHV), infectious myonecrosis virus (IMNV) and taura syndrome virus (TSV) have been reported to cause mass mortality and severe economic losses. In India, viral diseases such as WSSV, IHHNV, and IMNV have been frequently reported in shrimp aquaculture. White spot disease (WSD) is the most devastating disease of penaeid shrimp caused by white spot syndrome virus (WSSV). Infectious myonecrosis (IMN) is an emerging viral disease caused by IMNV. IMNV epizootics have been recorded recently in the Indian shrimp aquaculture industry. Lately, a microsporidian *Enterocytozoon hepatopenaei* (EHP), the causative

agent of hepatopancreatic microsporidiosis (HPM) has been reported to cause severe epizootics in shrimp farming. The production loss due to EHP in Indian shrimp farms was estimated to be about Rs. 3977 crores. Among, bacterial diseases, vibriosis, filamentous bacterial disease, and luminescent bacterial disease have been reported in shrimp hatcheries and grow-out farms. Lately, acute hepapancreatic necrosis disease (AHPND) or early mortality syndrome (EMS) has significantly affected the shrimp culture in south-east Asian countries. However, AHPND was not reported so far from the Indian shrimp aquaculture sector. Apart from the major diseases, several management-related syndromes or diseases with unknown aetiologies, such as running mortality syndrome (RMS), white feces syndrome (WFS), white muscle syndrome (WMS), stunted growth/growth retardation, and black gill have been constantly associated with the shrimp culture.

A number of emerging diseases and diseases with unknown etiologies are frequently challenging the shrimp aquaculture industry and are responsible for either direct mortality or growth reduction, thereby bringing substantial economic loss to the farmers. The HPM caused by *Enterocytozoon hepatopenaei* (EHP) and the WFS syndrome with unknown etiology have been the serious concerns and reported to cause severe economic losses in shrimp aquaculture.

Hepatopancreatic microsporidiosis (HPM)

Hepatopancreatic microsporidiosis (HPM) is the disease caused by microsporidian pathogen EHP. The microsporidian parasite was reported to affect the black tiger shrimp *Penaeus monodon* in Thailand in the year 2009. Since then, EHP has been widespread in most of the Southeast Asian countries, including India. It is referred as hepatopancreatic microsporidiosis (HPM) since the parasite is confined to the shrimp hepatopancreas (HP). EHP infection did not cause mass mortality but was reported to be associated with stunted growth and WFS. EHP inflicts reduced feed consumption, stunted growth, and severe production losses.

Host range, distribution and prevalence

The epizootics and spread of EHP were reported in different shrimp farming nations, including Taiwan, Malaysia, Brunei, Vietnam, Venezuela, Korea, Australia, and India. In India the spread of EHP has been recorded in both and west coasts. Co-infection of EHP has been recorded with other viral diseases such as WSSV, IMNV, TSV, HPV and with bacterial diseases such as AHPND and *Vibrio* spp. This microsporidian is reported to infect Penaeid shrimps species: *Penaeus monodon*, *P. vannamei*, *P. indicus* and *P. merguensis*. Many aquatic invertebrates organisms such as polychaetes, artemia, wild crabs, small aquatic crustaceans, insects, molluscs etc. also act as carriers for this pathogen.

Clinical signs



Fig. EHP affected shrimp show size variation and stunted growth

Shrimp infected with EHP do not have any specific signs when they are small. The main clinical signs of EHP at the farm level is slow growth/growth retardation leading to size variation (Fig.). EHP infects HP, affect the physiology, metabolism and inturn the shrimp growth. Also, EHP infected shrimp display reduced feed intake, increased food conversion ratio (FCR), empty gut, lethargy and display soft shells. EHP infection did not cause mass mortality but severe infection result in daily mortalities. It is also associated with occurrence of WFS as the infection progress. EHP-WFS affected shrimp exhibit gold brown/white intestine, loose shell, and excreting white fecal strings. Severe infections by EHP can increase the susceptibility of shrimp to other bacterial infections due to *Vibrio* spp. in shrimp farms and can result in mortality.

EHP transmission

EHP can infect shrimp at all stages of development and at various salinity levels of many penaeid species. Transmission of the disease mainly occurs by oral route. Shrimp may get infected by consuming feed contaminated with faeces and through cannibalism of infected shrimp or even by consuming spores present in the pond water and sediment. However, the vertical transmission of EHP from female brooders to the offspring is unlikely. Many invertebrates such as polychaetes, artemia, wild crabs, small aquatic crustaceans, insects, bivalves, etc. also act as carriers for EHP. In hatcheries, polychaete worms are considered as main carriers for the EHP infecting the shrimp broodstock.

Pathology

EHP is an intracellular spore-forming parasite. It replicates within the cytoplasm of the tubular epithelial cells of the hepatopancreas. EHP infection causes severe

necrosis and dilation of HP epithelial tubules, increase in the hemal sinus, and sloughing of epithelial cells. Characteristic histopathological features of EHP include the presence of any life stages or free and mature EHP spores in HP cells. Early stages of EHP infection stained with hematoxylin and eosin are observed as eosinophilic to basophilic inclusions and mature spores are refractile.

EHP diagnosis

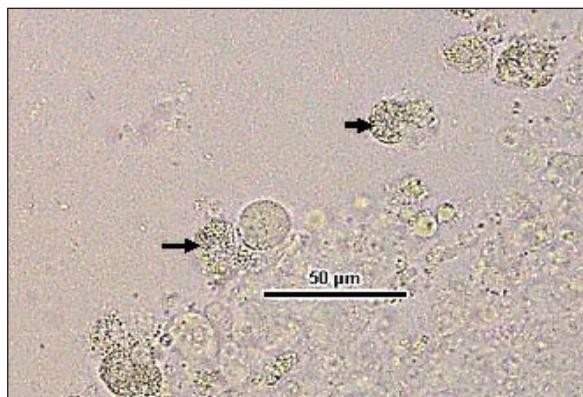


Fig. Wet mount of hepatopancreas showing *E. hepatopenaei* spores inside the hepatopancreatic tubular epithelial cells under light microscopy

The EHP can be diagnosed by demonstration of spores in fecal sample and in hepatopancreas by microscopic examination (Fig.). Spores can also be demonstrated in the affected animals by different stains such as Giemsa, phloxin, trichrome, calcofluor white, hematoxylin and eosin. Histology of infected tissues reveals several developmental stages, including plasmodium and spore stages. But microscopic demonstration remains successful only in severely affected cases and often undetectable in the early infection. However, many molecular methods such as PCR, qPCR, Loop mediated isothermal amplification (LAMP), are available for screening the pathogen. These techniques are faster, easier and far more accurate to detect the EHP in feces, post-larvae and hepatopancreatic tissue.

Prevention and control of EHP

EHP - When to diagnose?

Brooders should be checked for EHP before stocking in hatcheries. PL should be tested for EHP if any growth retardation, reduced feeding activity, slow moulting, and enlarged hepatopancreas tubules. Shrimp seeds should be checked for EHP before stocking in ponds. Similarly, the grow-out shrimp should be checked for EHP

if any growth retardation, white/golden shrimp gut, or floating white faecal threads are observed in shrimp ponds.

Management of EHP in hatcheries

For larval production, only SPF brooders/ EHP negative brooders should be used. The live feeds and other feed inputs should be tested for EHP by PCR. Also, the live feeds should be pasteurized at 70°C for 15 min or frozen at -20°C for at least 48 h before feeding brooders instead of feeding in live conditions. Effective disinfection should be followed to inactivate EHP spores. The hatchery facilities such as tanks, pipelines, and other implements can be disinfected with 2.5% sodium hydroxide for 3 hrs followed by drying for a week.

Management of EHP in grow-out ponds

In shrimp ponds, only EHP negative seeds should be stocked. Once spores are entered in ponds, it is very difficult to eradicate the disease. Hence farmers should adhere to strict biosecurity protocols and adopt better management practices (BMPs). Pond preparation should be carried out by proper drying and disinfection after every harvest to ensure that the EHP spores along with the carriers are destroyed. Treatment of pond sediments by application of CaO (quick lime) @ 6 tons/ha has been recommended. It is advised to apply the CaO into the dry pond sediment (10-12 cm) and then moisten the sediment to activate the lime. Also, it is recommended to use >15 ppm KMnO₄ or >40 ppm chlorine to inactivate spores in the soil. The pond should be left for one week for drying before filling. Pond bottoms should be kept clean; accumulating organic matter can act as a spore reservoir. Poly aluminium chloride can be used to coagulate, flocculate, and sediment the suspended organic material including spores which can then be removed/pumped away. Any new water should be treated before entering the ponds to avoid reinfection. Also, nursery rearing can be implemented in the shrimp culture system. The nursery phase of culture and subsequent PCR testing may be useful in intersecting disease transmission and massive contamination into the grow-out ponds. Strict biosecurity measures and better management practices should be implemented to prevent EHP.

White feces syndrome (WFS)

White feces syndrome (WFS) has emerged as a serious concern for global shrimp aquaculture in recent years. Affected shrimp excrete white feces and affected ponds were observed with floating white fecal threads. The syndrome has been reported both in cultured *P. vannamei* and *P. monodon*. In India, since 2015, the occurrences of WFS were very severe in *P. vannamei* grow-out farms. The disease can

cause moderate to severe economic loss by reducing the shrimp survival by 20–30% compared to the normal ponds.

Clinical signs of WFS

The shrimp affected with WFS can exhibit clinical signs as early as 20-30 days of culture. The WFS affected shrimp exhibit white/golden brown intestine, excrete white fecal threads and show reduced feeding and retarded growth. Ponds affected with WFS shrimp show floating white fecal threads on the surface of the pond for 10 to 45 days or more and will have increased FCR, size variation/growth retardation, loose shells and daily mortalities (Fig.). The animal affected with loose shell show loose exoskeleton and sluggish swimming activity at the pond surface.



Fig. A- Shrimp with normal gut and WFS shrimp with white gut. B - White fecal threads floating on the WFS affected shrimp pond surface.

Pathology

Severe damage of WFS-affected shrimp hepatopancreas result in vermiform bodies. Vermiform bodies are ATM structures that are formed due to aggregated transformed microvilli (ATM) from HP cells. Severe accumulation of vermiform bodies in affected shrimp result in white feces. Squash, smear preparation, and histology section of WFS affected HP can show the vermiform bodies. EHP is an intracellular parasite that proliferates within the cytoplasm of the affected tubule epithelial cells in the hepatopancreas. Hence, the squash and smear preparations of hepatopancreas at higher magnification (100x) reveal sporoplasms and dense spores. Histology of infected tissues reveals several developmental stages, including plasmodium and spore stages (Fig.).

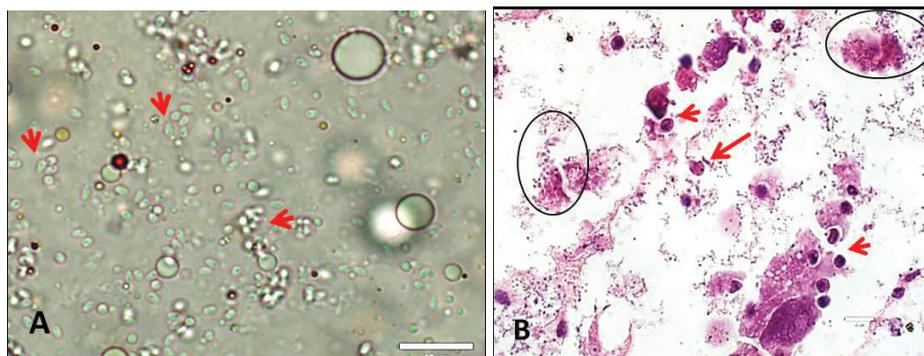


Fig. A- Squash preparation of WFS HP show dense mature EHP spores, B- Histology section of WFS HP stained with H&E show severe necrosis, sloughed off epithelial cell (long arrow), spores (circle), and plasmodial stages (short arrow)

Causative agent

The etiology of WFS is more complex and is reported to be caused by more than one pathogen. So far the incidences of WFS have been associated with gregarine worms, *Vibrios*, EHP, bacteria, fungi, and algae. However, white fecal strings are primarily composed of dense mature EHP spores, and vermiform bodies, sloughed-off epithelial cells, gut mucus, and rod-shaped bacterium observed in white feces. Also, WFS was reproduced under laboratory experimental conditions by challenging EHP infected tissues, EHP and *Vibrio parahaemolyticus* and by specific *Propionigenium* and specific *Vibrio* in combination with EHP. Furthermore, the gut microbiome of EHP-infected shrimp is significantly different from that of healthy shrimp. When EHP infiltrates, the abundance of the hepatopancreatic and gut microbiome decreases significantly. Along with this, there is an increase in disease-causing bacterial groups replacing the beneficial bacterial groups from the gut. This change in gut bacteria is a precursor to the progression of WFS. The clinical manifestation of WFS is more complicated and similar to a clinical condition such as diarrhoea. Thus EHP-WFS is a clinical condition caused by EHP in combination with *Vibrio* sp./other pathogens.

Management

Occurrence of WFS can be reduced by good management practices and proactive biosecurity measures in the farm. Feed can be reduced during the WFS affected period in shrimp ponds. Floating white fecal strings can be frequently removed from the shrimp pond on day to day basis. Nutraceuticals/feed additives which improve HP regeneration and epithelial cell proliferation might help the shrimp to recover from WFS condition in the affected ponds. Overfeeding should be avoided; energy spent

in digestion will only weaken the shrimp. Also, a high protein diet can be used during the infection to help the shrimp's digestive capacity and recovery of the HP. Since the role of gregarine is negligible in WFS, anti-gregarine treatment may be avoided. Since EHP is significantly associated with the occurrences of WFS and is considered one of the causes of WFS. Hence the management measures recommended against EHP can be followed in WFS affected farms. In grow-out ponds, EHP-free PL should be stocked in the ponds. Pond preparatory measures should be followed properly by drying and disinfection after every harvest. Calcium oxide (CaO) / quick lime at 6 tons/ha can be used by ploughing into 10-12 cm followed by moistening to activate the lime. Potassium permanganate > 15 ppm and Chlorine > 40 ppm can be used to inactivate the spores in the soil. Better management practices should be strictly followed.

Conclusion

Hepatopancreatic microsporidiosis and white feces syndrome are emerged as major constraints for shrimp aquaculture. EHP targets shrimp hepatopancreas and affects shrimp physiology, metabolism, immune system and in turn results in growth retardation. The key to controlling EHP is to always keep the shrimp healthy. When shrimp have good immunity and growth, they can easily resist the effects of EHP as well as effectively combat other opportunistic pathogens from the environment. The concept of nursery rearing and PCR testing before stocking into grow-out ponds can be implemented to intercept the disease transmission and avoid massive contamination. WFS is a clinical condition manifested by EHP in combination with *Vibrio* / unknown pathogen in EHP-endemic countries. WFS treatment strategies may include the components having anti-EHP activity and anti-bacterial activity, since WFS etiology involve both EHP and bacteria. Always, better management practices should be followed strictly for the prevention of HPM and WFS.

SMART FARMING AND REAL-TIME DATA BASED SHRIMP FARM MANAGEMENT: PRESENT STATUS AND ITS SCOPE FOR IMMEDIATE FUTURE

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Introduction

Aquaculture plays a significant role in providing, improved nutrition, food availability and security with real-time data-based farm management involves the integration of technology and data analytics to optimise the production and efficiency of farming operations. By using the Internet of Things (IoT), artificial intelligence, IT devices, advanced monitoring systems and tools like drones, autonomous tractors, sensors, robotics and data analysis, the farmers can make informed decisions, automate processes, and ensure optimal conditions for shrimp growth, and improve the efficiency and sustainability in farm management. Artificial Intelligence (AI) controlled aquaculture farms are capable of performing comprehensive fine control on various aspects, including water quality management, intelligent feeding, behaviour analysis, biomass estimation, disease diagnosis, equipment operating condition, and defect warning. Precision farming facilitates more autonomous and continuous monitoring, improves the accuracy, precision, and repeatability of farming operations, provides higher reliable decision support, and reduces dependencies on manual labour.

1. Smart farming tools and systems

Smart farming technologies encompass a range of advanced technologies/tools/systems and data-driven approaches that help to identify patterns, correlations, and trends, enabling farmers to make data-driven decisions and optimise farm management practices.

- a) Wireless sensor networks (WSNs): WSNs enable the deployment of interconnected sensors throughout the farm, providing real-time data on environmental conditions. These networks facilitate comprehensive monitoring and analysis of multiple parameters simultaneously.
- b) Internet of Things (IoT): IoT technology connects devices and systems in a shrimp farm, enabling data sharing and automation. For example, sensors, feeders, and environmental control systems can be integrated to create a cohesive smart farming ecosystem.

- c) Artificial intelligence (AI) and Machine learning (ML): AI and ML algorithms can analyze large datasets to identify patterns, correlations, and trends in shrimp behaviour, growth rates, and environmental conditions. This data-driven approach helps to optimize farm management decisions.
- d) Imaging and computer vision: Technologies such as underwater cameras and computer vision systems are being used for a variety of inspection tasks such as counting, size measurement and mass estimation, gender detection and quality inspection, species and stock identification, and behaviour monitoring. These systems allow for non-invasive monitoring of shrimp behaviour, growth, and health, which aids in identifying abnormalities or stress-related patterns.
- e) Robotics and automation: Robotic systems can assist in various farm operations, such as feed distribution, water quality management, and data collection. Automation reduces labour requirements and ensures precise execution of tasks.
- f) Unmanned vehicles or drones: Drones are currently used in aquaculture sites for gathering environmental data and observing fish behaviour. Unmanned surface vehicles (USVs) facilitate data collection and environmental monitoring. Remotely operated underwater vehicles (ROVs) and autonomous underwater vehicles (AUVs) are equipped with cameras to capture images and videos and collect water quality data. Advancements in drone technology have seen the development to retrieve water samples and physico-chemical data from aquatic ecosystems and dispense the feed and chemicals over aquaculture ponds.
- g) Laser scanning technology: It is another noninvasive monitoring technology that can be used to estimate fish biomass in real time. The total biomass of fish is generally estimated by the product of the density (ρ) and volume (V) of the fish.
- h) Remote monitoring and control: Farmers can remotely monitor and control various farm operations through mobile apps or web-based interfaces. Through a centralized system, farmers can access real-time data, receive alerts, and make adjustments to environmental conditions, feeding schedules, and water management systems from anywhere, improving farm management efficiency. This allows for real-time monitoring, data analysis, and prompt intervention, even when farmers are off-site.



Fig. Feed dispensing in shrimp ponds through drones

2. Real time data based shrimp farm management

Real-time data-based shrimp farm management involves the collection, analysis, and utilisation of real-time data to make informed decisions and optimise various aspects of shrimp farming.

- a) **Data collection:** Implement sensors and monitoring systems to collect real-time data on various parameters relevant to shrimp farming. This includes water quality parameters, temperature, dissolved oxygen levels, feeding patterns, growth rates, and disease indicators.
- b) **Data integration:** Integrate data from multiple sources, such as environmental sensors, feeding systems, disease monitoring systems, and other farm management tools. This allows for a holistic view of the farm's operations and performance.
- c) **Data analysis:** Utilize data analytics techniques and algorithms to analyse the collected data in real time. This involves identifying patterns, correlations, trends, and anomalies to gain insights into shrimp health, growth, environmental conditions, and other key factors. Data analytics techniques, such as trend analysis and pattern recognition, can identify correlations, anomalies, or early warning signs of water quality problems. This enables proactive measures and preventive actions to maintain optimal conditions.
- d) **Decision-making support:** Data analytics tools and decision-support systems assist farmers in making informed decisions based on data-driven insights. Real-time data insights enable farmers to make informed decisions regarding feeding strategies, water quality management, disease prevention and treatment, and other critical aspects of shrimp farming such as production planning and forecasting systems, financial management systems, etc.

- e) Automation and control: Implement automated systems and control mechanisms that can be adjusted based on real-time data analysis. For example, automated feeding systems can adjust feed quantities based on shrimp growth rates, while environmental control systems can optimize water quality parameters based on real-time data.
- f) Alert systems: Set up alert systems that trigger notifications or alarms when specific thresholds or conditions are met. This allows farmers to respond promptly to any deviations or critical events in the farm environment, such as sudden changes in water quality or disease outbreaks.
- g) Historical data analysis: Analyse historical data collected over time to identify trends, patterns, and correlations. This helps in understanding long-term performance, identifying areas for improvement, and making data-driven decisions for future farm management strategies. Historical data analysis helps identify patterns, trends, and correlations between water quality parameters and shrimp health or growth. It allows farmers to make data-driven decisions and optimize their farm management practices.
- h) Predictive analytics and forecasting: By combining historical data with real-time monitoring, predictive analytics can be used to forecast shrimp growth, anticipate market demands, and optimize production planning. These forecasts enable farmers to make informed decisions regarding feed procurement, harvesting schedules, and market timing.
- i) Integration with farm management software: Integrate real-time data and analytics capabilities into a centralised farm management software or platform. This enables a comprehensive view of the farm's performance, facilitates data visualization, and assists in data-driven decision-making.

Real-time data-based shrimp farm management provides farmers with the ability to make proactive decisions, optimize resources, reduce risks, and improve overall farm productivity and sustainability. By leveraging real-time data insights, farmers can enhance shrimp health, growth, and profitability in a data-driven and efficient manner.

3. Smart farming and real time data based applications in shrimp farming

Some of the important smart shrimp farm management technologies being explored are water quality monitoring and management, feed monitoring and management, and disease identification and prevention.

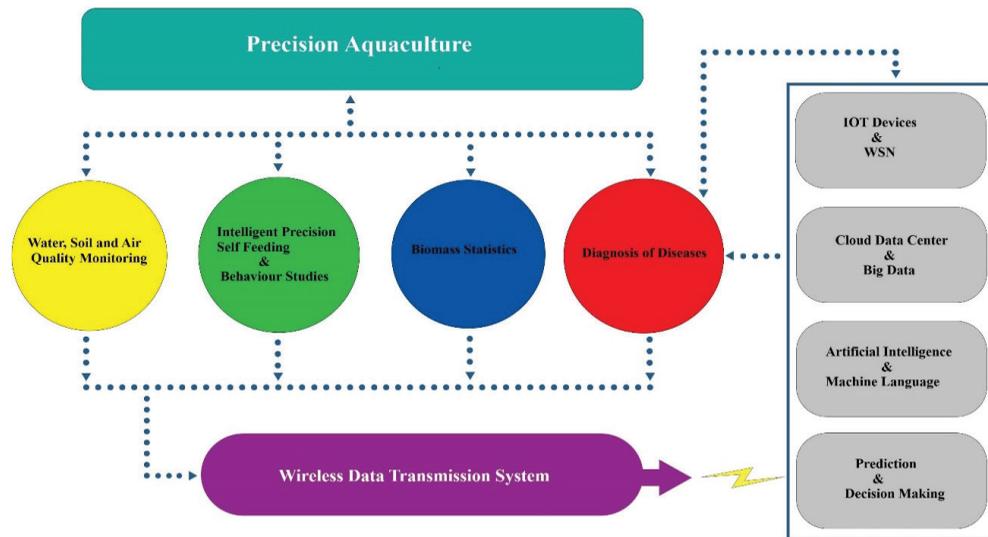


Fig. Schematic representation of AI and IOT applications in aquaculture

A. Water quality monitoring and management

Shrimp are highly sensitive to changes in water quality. Smart environmental monitoring in shrimp farms involves the use of advanced sensors, monitoring systems, and data analysis techniques to ensure optimal environmental conditions for shrimp growth, reduce the risk of stress or disease outbreaks, and enhances overall farm productivity. Real time water quality monitoring involves the continuous monitoring of key parameters such as water temperature, pH, dissolved oxygen, salinity, ammonia, nitrite, turbidity, algae and phytoplankton populations, etc. by deploying water quality sensors in shrimp farms. Water quality sensors are connected to a network that allows for data transmission in real time. Wireless connectivity options, such as Wi-Fi or cellular networks, enable the sensors to send data to a central monitoring system or cloud-based platform. A central monitoring system collects and processes the data received from the sensors in real time. It provides a centralized view of water quality parameters, allowing farmers to monitor the conditions at a glance and to ensure that water parameters are within the optimal range for shrimp growth and health, identify any deviations that could impact their health, and proactive measures to maintain a healthy and productive shrimp farming environment.

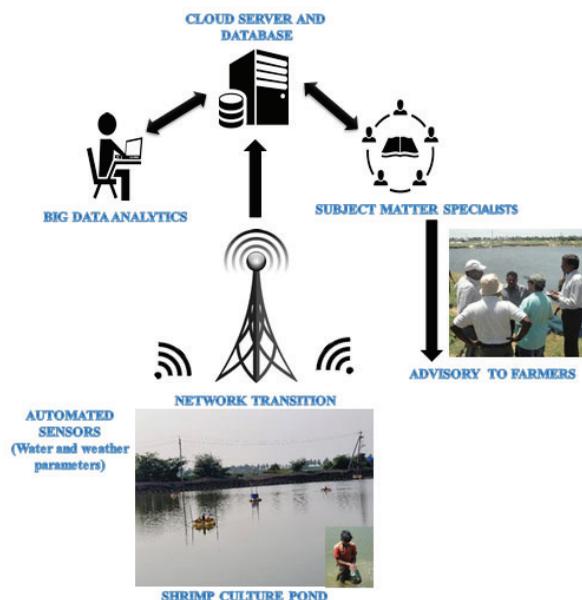


Fig. Schematic representation of wireless sensor network for water quality monitoring

Integrating sensors with automated control systems enable real-time adjustments to maintain optimal water quality. Automated systems can adjust water circulation, aeration, and filtration processes to maintain optimum water quality, reducing the risk of disease outbreaks and improving overall shrimp health. Automatic oxygenation and aeration systems adjust the oxygen levels in the water based on real-time data. For example, if the dissolved oxygen level falls below the desired threshold, the control system can activate aerators or oxygenation devices to increase oxygen levels. This ensures that the shrimp have sufficient oxygen for respiration, especially in high stocking density situations. Proper water circulation and filtration are essential for maintaining water quality and preventing the accumulation of waste materials that can be harmful to shrimp. Smart monitoring systems can regulate water circulation and filtration processes based on data such as water quality parameters and stocking density, ensuring efficient removal of waste and maintenance of optimal conditions. Similarly, if ammonia or nitrate levels rise, the system can initiate water exchange or activate biofiltration processes to remove toxins.

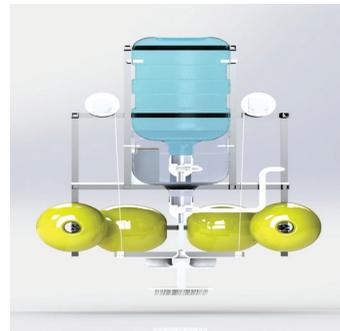
B. Feed monitoring and management

Smart and real-time feed management in shrimp farms involves the use of technology and data-driven approaches to optimise feeding practices and maximise

shrimp growth and productivity. Feed monitoring systems can utilise sensors, weight scales, or imaging technologies to track the amount of feed dispensed to the shrimp. Smart/automated feeders are programmed to dispense the accurate amount of feed at appropriate intervals based on the specific requirements of the shrimp. Smart feed management systems can be integrated with other environmental/farm management monitoring systems in the shrimp farm. Real-time data on shrimp behaviour, growth rates, feeding patterns, feed conversion rate (FCR) and water quality parameters can be used as triggers for feed dispensing to optimise feed delivery, reduce wastage, and ensure proper nutrition for the shrimp. For example, if the water temperature rises above a certain threshold, the system may trigger additional feed to support the increased metabolic rate of the shrimp. Real-time feed management systems can also incorporate feed quality and nutritional analysis. By regularly testing feed samples for their nutritional content and ensuring their quality, farmers can make informed decisions about feed selection and adjust feeding strategies accordingly. Farmers can monitor and analyze feed consumption trends, feeding efficiency, and other relevant metrics through intuitive dashboards and reports, allowing them to assess and optimize feed management practices. These systems enable data-driven decision-making, precision feeding, and optimization of feed quantities based on real-time information, leading to more efficient and sustainable shrimp farming operations.



Auto feeder in shrimp culture pond



Intelligent AI-IoT mobile dispenser of feed and drugs/chemicals

C. Disease detection and prevention

Real-time disease detection in shrimp farms involves the use of advanced technologies, data analytics, and monitoring systems to identify disease outbreaks. Real-time disease monitoring systems detect early signs of diseases through the analysis of water quality parameters, shrimp behaviour, and other indicators. Sudden shifts in water parameters such as temperature, salinity, and dissolved oxygen can

be an early warning sign of potential disease outbreaks. Real-time data analysis, combined with machine learning algorithms, can alert farmers to any deviations or patterns that indicate the presence of diseases, enabling prompt intervention and prevention measures. For example, if a disease outbreak is detected, the system can automatically adjust water quality parameters, isolate affected populations, or trigger specific disease management protocols.

Monitoring biomarkers in shrimp, such as immune responses, metabolic activities, and genetic expressions, can provide insights into their health status. Real-time analysis of these biomarkers, either through blood tests or non-invasive methods, can help identify early signs of diseases and enable prompt intervention. Implementing disease surveillance programs involves regular sampling and testing of shrimp populations for common diseases or pathogens. Real-time monitoring of test results helps farmers quickly identify and isolate infected individuals or populations, reducing the spread of diseases within the farm. Historical data on disease occurrences and environmental conditions can be leveraged to develop predictive models for disease forecasting. Through remote communication channels or online platforms, farmers can consult with shrimp disease specialists and receive guidance on disease management strategies. By implementing real-time disease detection and forecasting in shrimp farms, farmers can detect diseases at early stages, minimise losses, and implement targeted disease management strategies.

4. Conclusion

Smart farming and real-time data based shrimp farm management offer numerous benefits such as improved productivity, optimized resource utilization, reduced risks, improves overall farm management efficiency and enhanced sustainability. By combining advanced technologies, real-time monitoring, data analysis, and automation, farmers can optimise shrimp growth, minimize losses, and achieve sustainable and profitable shrimp farming operations. Incorporating energy-efficient technologies, renewable energy sources, and sustainable farming practices helps to minimise environmental impact and promote resource conservation. However, interoperability poses a significant challenge as sensors currently cover a wide range of types, suppliers, and levels of sophistication. These technologies are still under development and expensive for real use.

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CUSTOMIZABLE COMPACT SHRIMP FARMING SYSTEM FOR PRECISE USE OF LAND, WATER, FEED AND ENERGY

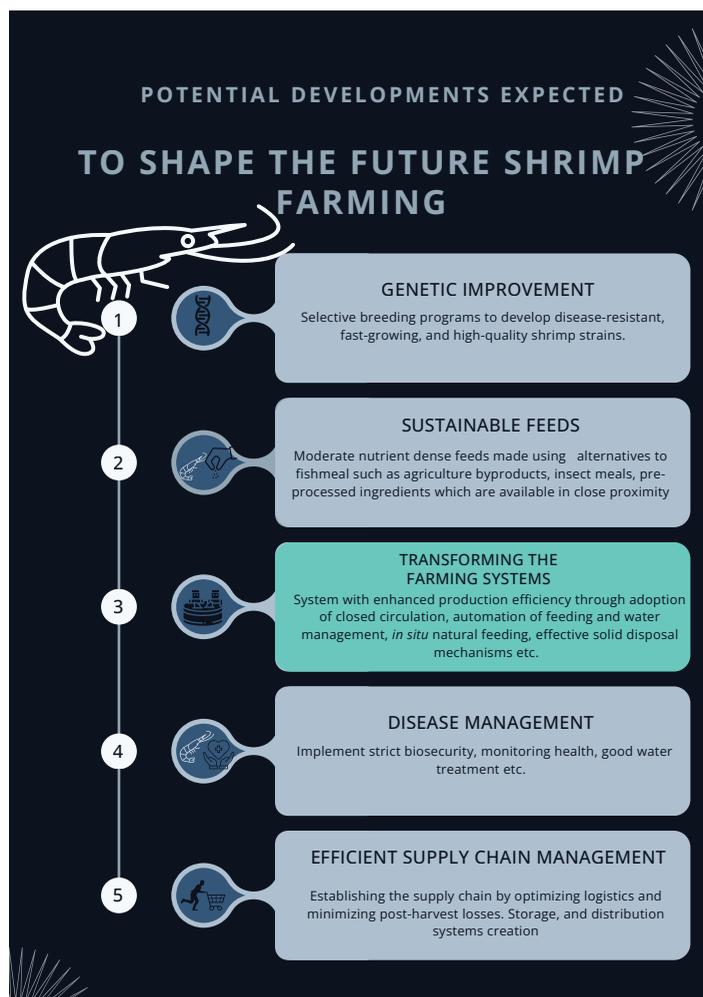
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Introduction

India being a significant contributor in global shrimp production and trade faces several challenges in farming due to a volatile export market, drop in international price, increase in the cost of production, disease risks, etc. As this is typical of any industry producing perishable foods, it may or may not recover in near future. However, there are some strategies for profitable shrimp farming with the implementation of modern scientific developments blending engineering, biology and business tactics.

Selectively bred, specific pathogen-free (SPF) Pacific white shrimp (*P. vannamei*), farmed widely in India, is fast growing and amenable for high-density farming up to 300 shrimps/ m² in highly engineered farming systems. The existing conventional large earthen ponds without proper engineering design use more water, more feed and more energy but can only accommodate low stocking density (30-50/ m²), yielding less productivity. With such a conventional farming system, the full growth potential of the shrimp could not be realized. Further, the culture of shrimps in such systems causes frequent failures, severe economic loss, and it increases the footprint on land and water. Therefore, present-day shrimp aquaculture is questioned for its economic viability and sustainability issues. It has been widely evidenced that, as husbandry and feed inputs are playing critical role in managing any live animals for commercial production, and it has been proven that alterations in the farming system and farming methods in alignment to the technology access and resources availability will leads us to overcome these challenges. Therefore, transforming the rearing system is essential and may be a solution for many of the challenges the farmers facing today.

To upkeep the shrimp aquaculture as a profitable agribusiness, next generation of shrimp farming is likely to involve the potential advancements in science and technology. Here are some potential developments that are expected to shape the future of shrimp farming:



As many of these elements pictured above are described in detail by the other chapters of this farmer's hand book, here we describe the concept of "transforming the farming system and strategies" with options for customization based on the resources available.

The farmers' choice of shrimp rearing system is influenced by the following factors

- ❖ Prevailing climatic conditions in that region
- ❖ Location of the farm site
- ❖ Land, water, power availability and cost

- ❖ Access and transportation
- ❖ Financial capabilities
- ❖ Labor availability and cost
- ❖ Feed and other inputs, their availability and cost
- ❖ National planning guidelines regulations
- ❖ Existing market and final product price

Considering the above listed parameters one can customize the size and the level of complexity. We hope that this article will assist you to understand concepts and guide to do a customization accordingly.

Enhancing shrimp productivity by using the services of co-cultured microbes, algae, copepods, planktonic organisms and associated biofloc (microcosm) is scientifically proven and gaining attention as a sustainable approach. Here, microbes not only maintain water quality, but they themselves also act as a nutritious *in situ* natural feed. This situation offers scope for decreasing the feed inputs and increasing the shrimp stocking density, nutrient recovery and productivity. This approach also allows us to operate the system with less water (zero water exchange) and less energy use. But proper integration and close monitoring of the critical parameters are crucial, and this needs modern engineering and technology.

We have witnessed converting the conventional ponds to biofloc based farms by amending two or more elements is not successful due to poor integration and operational complications. Therefore, here we suggest a complete microcosm-based system involving circular self-cleaning ponds, natural feed, automation and zero water exchange focusing on effectual use of land, water, energy, and feed. The core vision should be to integrate the modern engineering and advances in shrimp aquaculture in water management, feed management through an intensified ecosystem approach, which leads to precision farming with efficient use of energy, water and land.

Concept of new age shrimp rearing system combining biofloc technology, recirculation and solid waste removal for sustainable intensive shrimp farming

The fundamental element of the explained compact farming module is four circular interconnected HDPE lined ponds (300-500 m³) with central drainage and self-cleaning system, and an elevated nursery tank. This system will be operated in such a way to have plenty of natural feeds (biofloc), water reuse, precise use of feed (automation), energy (logical sensors) and land etc., to make shrimp farming more productive, economical, and environmentally sustainable.

Designing and construction of the biofloc and RA-based hybrid shrimp production system with modern engineering to have recyclable HDPE Geomembrane lined four circular grow-out ponds and one centrally placed nursery in an elevation to facilitate the transfer of shrimp juveniles by gravity. Alternatively, similar unit can be above the ground level, using GI framed metal structure and HDPE geo membrane with required amount of slope and a central drain. In this model, nursery also will in the same plane, so transfer of juvenile from the nursery to grow-out can be done by harvest transfer.



Fig. Conceptual 4+1 shrimp farming system with central drainage and self-cleaning system, and an elevated nursery tank

Such a strategically placed 4+1 tanks will form a one-rearing unit. All the grow-out ponds could be interconnected through a valved pipe of suitable sizing for circulating the water by gravity (40-50%) and pumping (remaining) in an integrated way. All the ponds/tanks must have a sub-surface central drain with a dual drain to facilitate self-cleaning and *in situ* self-digestion of the settleable organic materials by pushing back and dispersing back to the pond water on a continuous manner. Aeration can be provided to the precise requirement for shrimp and microbial biomass requirement (calculated biological demand), which is continuously monitored by logical sensors connected to aerators. Mixed aeration could be provided with a paddle wheel/air injectors and aero tube diffusers. Shrimps are to be fed using automatic feeders to maintain a precise use of feed. More the feeding frequency for the given daily ration, feed will be better utilized and farmer can make a huge saving in the feed portion. Total suspended solids should be monitored often, if found in excess (>25) should be disposed as when through the central settlement drain.

This engineered system is expected to support mechanized feeding, enough biofloc production, and frequent removal of solid wastes and free of anaerobic environment. By having such a handy system, there will be an enough potential to

increase the stocking density of the shrimp in unit area of space and time. This also will greatly reduce the cost of production. Also, there is potential for reduction in cost of production on systematic investments in use of feed, water, aeration and manpower.

Points to be considered in construction of the rearing unit

As described above the 4+1 rearing unit can be a circular pond of small size (500 – 800 m³) or it could be circular tanks of size ranging from 300 to 600 m³ installed above the ground using galvanized metal frame and pond liner material. The choice is up to the farmer based on the resource availability and topography of the land. There are different grades of pond liner material available in the market nowadays.

PVC, EPDM, and HDPE are all materials that are commonly used for various applications, including as liners for shrimp ponds. Here is a brief comparison of these materials:

1. **PVC (Polyvinyl chloride):** PVC is a synthetic material that is known for its durability, flexibility, and resistance to chemicals, UV radiation, and punctures. PVC liners are relatively inexpensive and easy to install, making them a popular choice for small to medium-sized shrimp ponds. However, PVC liners may degrade over time and can release harmful chemicals into the water.
2. **EPDM (Ethylene Propylene Diene Monomer):** EPDM is a synthetic rubber material that is known for its high elasticity, durability, and resistance to UV radiation and chemicals. EPDM liners are more expensive than PVC liners but are also more durable and longer-lasting. EPDM liners are also more resistant to punctures and tears, making them a good choice for larger shrimp ponds.
3. **HDPE (High-density polyethylene):** HDPE is a synthetic material that is known for its strength, durability, and resistance to chemicals and UV radiation. HDPE liners are more expensive than PVC liners but are also more durable and long-lasting. HDPE liners are also more resistant to punctures and tears than PVC liners, making them a good choice for larger shrimp ponds or those located in areas with sharp rocks or debris.

Overall, the choice of liner material depends on various factors such as the size of the pond, the water quality, and the specific needs of the shrimp being cultivated. A qualified aquaculture expert can help determine which type of liner material is best for a particular shrimp pond. In general HDPE liners are by and large recommended for shrimp aquaculture in the Indian conditions.

HDPE pond liner sheets come in a variety of dimensions and thicknesses. The dimensions and thickness of the liner depend on the size of the pond and the specific needs. Here are some common dimensions and thicknesses for HDPE pond liner sheets:

Dimensions

Width: Typically ranges from 20 to 50 feet (6 to 15 meters).

Length: Can be customized to fit the size of the pond.

Thickness: Ranges from 20 to 80 mils (0.5 to 2 millimeters).

Thickness

- ❖ 20 mil (0.5 mm): Suitable for small and less maneuver ponds.
- ❖ 30 mil (0.75 mm): Suitable for small to medium-sized ponds with moderate water volume.
- ❖ 40 mil (1 mm): Suitable for medium-sized ponds with moderate to high water volume and moderate maneuver.
- ❖ 60 mil (1.5 mm): Suitable for larger ponds with high water volume and high maneuver.

It is important to consult a qualified aquaculture expert to determine the appropriate dimensions and thickness of the HDPE pond liner sheet for a particular shrimp pond. The expert can take into account various factors such soil nature, topography, water quality, and the specific needs of the pond.

Farming strategies in the compact 4+1 shrimp farming systems

While only two farming cycles are possible in the existing conventional farming system, compact new age shrimp farming system offers a chance of year-round production with efficient utilization of land, water, energy and feed inputs. Every month the centrally placed nursery tank will be stocked with fresh PLs screened for all the known diseases. After a month the juvenile shrimps of 1 g size (approx.) will be restocked in one of the grow-out ponds and further reared for three months until harvest. On the same day the nursery can be stocked with second batch PL's and reared for a month. This batch will go in to the Grow out pond 2 and likewise Pond 3 should be stocked next month. While the fifth batch of PL's are stocked in the nursery tank, Tank no. 1 will be ready for harvest. Immediately after harvest this tank can be stocked with fresh batch of juveniles ready in the nursery tank. If required a high stocking and partial harvest model can be implemented based on the business plan and resource scenario. Further during the harvest the water from the grow out tank can be transferred to the neighboring tank by gravity (40%) and remaining by

pumping. This will help in saving water, feed and energy through better nutrient recovery from the matured water from grow out tank rich in natural feed organisms.

A comparison between conventional and new age shrimp farming system on the key parameters

	Conventional	New age
Physical aspects		
Pond shape	Rectangular	Circular
Pond volume (m ³)	4000 to 15000	350 to 500
Pond bottom	Earthen	HDPE Lined
Drainage type	Sluice gate	Central dual drain
Aeration	Continuous	Sensor controlled restricted
Farming aspects		
Nature of farming	Algal-based; Direct stocking	Biofloc-based mixed feeding
Feed	Pelleted feed	Pelleted feed
FCR	1.2 to 1.5	0.9 to 1.1
Growth (weekly gain; g)	1.5 – 1.8	1.8-2.0
Productivity (ton/ha)	10	30
Number of farming cycles/ annum	2	4 ; continuous; two-tier farming
Biosecurity level	Less	Can be maintained high
Harvesting	Bulk at the end	Monthly harvest
Disease risk	High	Less
Rate of water exchange	100-300%	20-30%
Energy consumption (kW/ ton of shrimp)	More	50% can be reduced
Capital Investment	Less	Very high

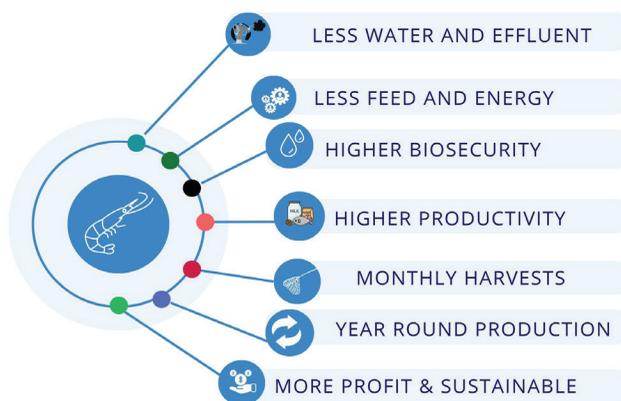
*This data was attained from existing conventional commercial operations and pilot scale microcosm based new age shrimp rearing system developed and tested in ICAR-CIBA

Highlights of the conceptualized new age shrimp farming system

- ❖ A unique monthly stocking and monthly harvest practice is possible by involving one nursery and four grow-out ponds. This will ensure a continuous monthly return to the farmer, which is not possible in conventional farming.

- ❖ It is fully bio-secured, hence the chances of disease outbreak is negligible.
- ❖ Modern automated feeding, integrated logical sensors (dissolved oxygen and pH), and self-cleaning mechanisms (solid disposal) will offer direct cost savings in feed, energy and workforce.
- ❖ Productivity of the shrimp farms is expected to triple per unit land area compared to the conventional systems.
- ❖ Entire water spread area of the rearing units covered with ecofriendly, durable, recyclable HDPE geomembrane. This is expected to save two-third of the water which is normally lost through seepage and will solve most of the water management issues.
- ❖ Using the services of co-cultured microbes, algae, copepods, planktonic organisms, and associated biofloc in treating the water in-situ and providing them as natural feeds to the shrimps will help us in the maximum recovery of nutrients and saves feed cost and water management cost.

ADVANTAGES NEW AGE SHRIMP REARING SYSTEM OFFERS



Care points

- ❖ The system is relatively advanced compared with traditional farming systems. It need a back-up power supply, water systems, aeration and alarm systems
- ❖ Workers need to be trained to operate with understanding the biological needs of the microbes, algae, zooplanktons and shrimps.
- ❖ The initial investment on capital items are relatively higher, and require a minimum production capacity for an economical operation.

Conclusion

To realize the enriched potentials of genetically improved shrimp strains, smart farming systems will play a significant role. Adopting modern way of farming in tank or compact circular pond based rearing system with options for water recirculation, disposal of waste, *in situ* natural feed generation, sensor-based water monitoring, AI, automation in feeding will enable precision farming under the framework of smart aquaculture. These advancements will lead to improved efficiency, reduce labor requirements, enhanced biosecurity and improve data-driven decision-making smart farming practice. Tailoring such as smart aquaculture system custom made to suit tropical Indian conditions has potentials to shape the future of shrimp farming and its overall sustainability. The PMMSY initiative has recently extended its support to design, develop, and demonstrate next-generation smart rearing systems in ICAR-CIBA premises, which are expected to be operational in the next few months.

INDIAN WHITE SHRIMP (*Penaeus indicus*) AS AN ALTERNATIVE SPECIES FOR DIVERSIFICATION AND SUSTAINABLE SHRIMP AQUACULTURE

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Introduction

The Indian white shrimp, *Penaeus indicus*, is a proven brackishwater aquaculture species that was one among the first shrimp species farmed along the coastal region until 1990s, prior to the demonstration of scientific shrimp farming using tiger shrimp. Commercial shrimp farming with selective stocking of seed began in India in the late 1980s with the breeding and seed production technology standardized by ICAR-CMFRI for *P. indicus* and *P. monodon*. However, due to the choice of farmers and higher economic returns on investment, commercial tiger shrimp farming gained dominance since 1990s, and Indian white shrimp has not received the attention it deserves. Following the emergence of WSSV in India and crop failures among Indian shrimp farmers since 1994, the introduction of genetically improved exotic, *Penaeus vannamei* was introduced to overcome WSSV-related crop failures. In 2022, the global shrimp production hit a record high of 9.4 million tonnes and 63 percent of all shrimps produced were farmed. Over half of the world's shrimp production was *P. vannamei* (FAO, 2023). In 2022, the shrimp market in India reached a volume of 0.85 million tonnes. The market is projected to expand at a CAGR of 9.60% from 2023 to 2028, and it is anticipated to reach a volume of around 1.47 million tonnes.

Due to the reliance of shrimp farming on a single exotic species, the industry is facing difficulties due to inbreeding, poor seed quality, and emerging diseases. And in such a scenario, a proven candidate species like *P. indicus*, native to the Indian subcontinent must be used for stock improvement through a selective breeding programme. ICAR-CIBA, a central institute for brackishwater aquaculture R&D in India, assessed the scientific data that were previously available for each species, paying particular attention to a stock enhancement project. It was not possible to start the selective breeding strategy for *P. indicus* since the basic data on the genetic stock structure and stock variation were not accessible. The endemic Indian white shrimp has a great deal of potential for standardisation for improving breeding and seed production through stock evaluation programme. In light of this, NFDB has funded the initiation of a cultural demonstration programme to examine the

performance of Indigenous Indian White shrimp, including stock appraisal, seed hatchery production, and scientific farming. In order to establish the baseline for the genetic improvement programme and to assess the usefulness of promoting our own indigenous species while emphasizing “Make in India” as opposed to imported species, different stocks across the Indian coast are compared for their culture potential.

As a substitute for Pacific white shrimp *P. vannamei*, this project will give the initial data needed to launch a selective breeding plan for the desi shrimp *P. indicus*. To encourage farmer adoption, ICAR-CIBA has under taken the demonstration of high/semi-intensive cultivation practices of this shrimp across a variety of production systems in several states. Indian white shrimp can be bred in captivity, and is feasible to generate high-quality, disease-free seeds. The seed production method was improved, and a subsequent farming demonstration revealed farmers’ enthusiasm in raising Indian white shrimps, perhaps leading to the diversification of the species. The multi-location culture trial of Indian white shrimp *P. indicus* was successful and revealed the following elements.

Species suitability of *indicus* for high density culture

- ❖ *It has an excellent growth potential and grows up to 18-20 g better or as fast as P. vannamei in different culture systems*
- ❖ *It is relatively easier to culture in high stocking densities*
Initial studies have shown a production of 3-4 tons/ha can be achieved at 25-30 no’s/sqm nearly at par with P. vannamei at similar stocking density. Further demonstration trials aiming higher level of production undertaken in multi-location across India. With further intensification, a production of 5-7 tons is reported to be achieved in this species. A density dependent growth pattern was observed.
- ❖ *It is tolerant to wide range of salinities 5 to 45 ppt*
- ❖ *This species is found to be compatible in the polyculture system with other fin fishes like mullets, milkfish and pearl spot and with other Penaeid shrimps.*
- ❖ *Various eco-based culture techniques, their potential for high density culture and technical efficiency of this species are being evaluated and initial studies are encouraging.*
- ❖ *It is easy to breed this species and hence its domestication is possible with the production of SPF stock due to the shorter generation period and easy captive breeding.*
- ❖ *Has same market values like other white shrimps, P. vannamei*

The native species of each country has its potential for diversification. The genetic improvement program of Indian White shrimp will aim to sustain the Indian shrimp aquaculture industry through the supply of domesticated genetically improved *P. indicus* broodstock for seed production and farming thereby augmenting aquaculture production and export. There is enough indication through preliminary trials that this species could be an indigenous alternative for *P. vannamei*. Commercial availability of SPF or high-health stock will be an added advantage.



Fig: *P. indicus* research and high-density culture demonstration by ICAR-CIBA

Why *Penaeus indicus* shrimp is viable?

- ❖ *Penaeus indicus* is our native species and easily adopts to our environment. Various studies show that *Penaeus indicus* farming can be profitable, based on factors such as growth performance, production, and economic viability. Additionally, there are ongoing efforts to optimize stocking density for improved farm management and sustainability.
- ❖ After establishing technologies in numerous regions across India, ICAR-CIBA has validated the Indian white shrimp farming through effective ways. Many demo cultures have shown a good survival rate, and it was most crucially used as a defender against illnesses.
- ❖ Several studies have indicated that nursery-grown (20-30 day) seeds have an advantage in terms of survival, growth, immunity, and feed utilization. Stocking nursery-grown seed (0.5-1g) instead of post larvae is becoming more popular among farmers due to compensatory growth, shorter grow out period, faster growth, and improved FCR.
- ❖ While avoiding numerous concerns associated to environmental difficulties and introduction of exotic infections, use of native species offers significant physiological benefits. High genetic diversity of *P. indicus* increases the efficacy of selective breeding programmes and gives shrimp farmers another choice for sustainable shrimp farming.

CIBA's achievements on *Penaeus indicus* shrimp farming

- ❖ Through partnership mode, nationwide frontline demonstrations of this desi shrimp were successfully carried out in many maritime states (Odisha, West Bengal, Andhra Pradesh, Tamil Nadu, Kerala, and Gujarat) with internal and external financial support from ICAR and the National Fisheries Development Board (NFDB).
- ❖ An ABW of up to 24-25 g, survival up to 90%, and a production ranging from 1.5 to 7.0 tons/ha were successfully attained under this nationwide multi-location culture trial with low- and high-density farming model (15 to 45 nos /tonnes), carried out at for 80 to 125 days of culture.
- ❖ A high survival of 95 to 98% with a production of 1.5 to 2.85 tons/ha was achieved under a sustainable farming approach of 10 to 15 nos/m² stocking in 80 to 120 days of culture.
- ❖ A low (15-20 no per m²) and high (45-50 no per m²) stocking density yielded a productivity of 3600-7800 kg per ha at 15-35 ppt and 2200-4400 kg per acre at lower salinity 3-10 ppt.
- ❖ When compared to the conventional single-phase grow-out system, productivity is increased by 20–30% when nursery is introduced.
- ❖ *P. indicus* requires less aeration because they are less susceptible to hypoxic conditions.
- ❖ Compared to *P. vannamei* shrimp, these local species of shrimp are comparatively disease-free in terms of white fecal and other diseases.

Table. Composite table comprising overall production performances of *P. indicus* in low and high stocking densities across different salinities along coastal states of India

Parameters	Low density	High density
Stocking density (PL/m ²)	10 to 20	25 to 45
Survival %	90 to 98	75 to 95
Average growth /week in g	1.5 to 2.5	1.0 to 1.8
FCR	1.0 to 1.4	1.3 to 1.8
Crop duration in days	90 to 120	90 to 135
Production tonnes/ha/crop	1.8 to 3.2	3.5 to 7.09
Size at harvest in g	22 to 30 g	17 to 23 g
Cost of production/kg in Rs.	180 to 210/-	210 to 240/-
Market price in Rs.	350 to 450/-	280 to 400/-
Disease incidences	Nil	5 – 8 %



Fig. Demonstration of desi shrimp *P. indicus* in various states of India

- ❖ The farm gate value ranges from Rs. 280 to 400 kg against a production cost of Rs 230/kg.
- ❖ The culture technology developed with SOP and important BMPs ensure production and reduced risks for promoting this indigenous species as a complementary species.
- ❖ Whole genome of *Penaeus indicus* was sequenced and assembled by Scientists of ICAR- CIBA. The genome (1.93 gb) could be assembled in 11171 scaffolds, with N50 value of 34.4 Mb. The whole genome sequence of shrimp is an invaluable genomic resource to aquaculture science researchers & shrimp breeders and would serve as a reference genome for future genetic improvement programmes for developing the shrimps with desired economically important traits.

Prospects of *Penaeus indicus* shrimp farming in India

- ❖ Farmed shrimps alone accounts for almost 70% of India's seafood exports worth Rs. 42000 crores. However, the shrimp farming industry is mostly dependent on a single alien species of Pacific white shrimp (*Penaeus vannamei*).

- ❖ It is extremely unsafe to rely on one species for 10 lakh tonnes of output, despite massive investments in farming infrastructure and the lives of two lakh farm families directly and nearly ten lakh households indirectly involved in auxiliary industries.
- ❖ Therefore, to break this single species dependence and to promote indigenous species vis-à-vis exotic shrimp species ICAR-CIBA has taken up the genetic improvement of programme of Indian white shrimp (GIPPI), *P. indicus* as a national priority under the Make in India flagship program which is funded by PMMSY.

Benefits of Genetic improvement programs for *Penaeus indicus*

- ❖ Genetic improvement programs for *Penaeus indicus* often involve collaborations between research institutions, government agencies, and shrimp farmers. These collaborations help in sharing knowledge, genetic resources, and best practices to achieve the desired genetic improvement goals.
- ❖ The genetic improvements developed through these programs are intended to benefit shrimp farmers and the aquaculture industry as a whole. The improved broodstock and technologies are transferred to farmers and hatchery operators, enabling them to enhance their shrimp farming operations and achieve higher productivity.
- ❖ Selective breeding: GI used to increase *Penaeus indicus* reproductive performance, including factors like fecundity (number of eggs produced), fertility (egg viability), and spawning frequency shrimp hatcheries. Improved reproductive performance can lead to larger stocking densities and higher output potential.



Fig. Biofloc based shrimp nursery system

- ❖ Adaptability to aquaculture systems: Genetic improvement programmes can aid in the development of shrimp strains that are more suited to the unique circumstances and management practices of shrimp farms. This includes features like resistance to changing water quality conditions,

temperature changes, and handling stress, which leads to increased survival rates and overall performance in aquaculture systems.

- ❖ Improved Growth rates: *Penaeus indicus* strains with faster growth rates can be generated by selective breeding and genetic enhancement. Faster-growing shrimps reach market size faster, resulting in shorter production cycles and higher overall productivity.
- ❖ Feed efficiency: Genetic improvement programmes can aid in the development of shrimp strains that are more effective in converting feed into body mass. *P. indicus* with higher feed conversion ratios require less feed to reach the appropriate growth rate, lowering total feed costs and the environmental effect of shrimp production.
- ❖ Disease resistance: Genetic improvement programmes can focus on increasing *Penaeus indicus* inherent resistance to illnesses. The development of disease-resistant shrimp strains can minimise the danger of disease outbreaks and the requirement for costly disease management methods, resulting in higher survival rates and lower economic costs.
- ❖ Consistency in performance: By focusing on genetic improvement, shrimp producers can obtain more consistency in their stock's performance. This results in more predictable and constant growth rates, survival rates, and total production, which is advantageous for planning and controlling production cycles, as well as satisfying market needs.
- ❖ Economic viability: When successful, genetic improvement programmes can lead to greater profitability and economic viability of shrimp farming businesses. Higher growth rates, greater feed efficiency, disease resistance, and improved reproductive performance can lead to larger production volumes, lower production costs, and higher market value of the shrimps produced.

Conclusion

Since the introduction of *P. vannamei*, the shrimp aquaculture industry in India has been revolutionized. However, the sustainability of the shrimp industry relies on the diversification of culture species for maximizing productivity. Indian white shrimp, *Penaeus indicus*, has been identified as a national priority species for domestication and genetic improvement. Diversification of production systems and adopting sustainable intensive systems are the need of the hour for doubling the production and income. The results from the studies especially that related to growth, survival, and production points out to the immense potential this species harbors for a selective breeding program for the improvisation of this indigenous species. The genetic improvement program of Indian white shrimp envisages to sustain the Indian shrimp aquaculture industry through the supply of domesticated SPF native broodstock for seed production and farming thereby augmenting aquaculture production and export.

MUD CRAB AQUACULTURE IN INDIA: STATUS AND WAY FORWARD

C.P. Balasubramanian, P.S. Shyne Anand, Jose Antony, I.F. Biju, R. Aravind
N.S. Sudheer, S. Kannappan and P. Partha Sarathy

Introduction

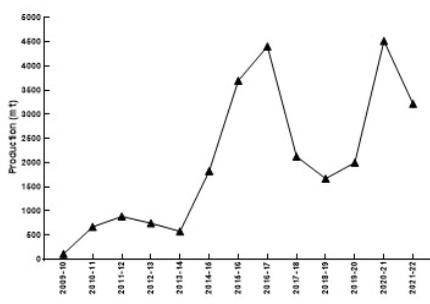
Mud crabs, species of genus *Scylla*, are immensely popular large brachyuran crabs because of its high price and established markets. They inhabit in the tropical and sub-tropical inter-tidal and sub-tidal zones, and in mangrove ecosystems of Indian ocean and western pacific regions. It has been recognized as a priority species for the diversification of coastal aquaculture in India and in many south east Asian countries. It is generally traded live and popular for its size, dense meat, and exclusive flavor. Soft shell crabs, smaller freshly molted crabs, have demand in European and U.S market in addition to the Asian market such as Singapore, China, Hongkong, Taiwan, Korea and Malaysia. In India, although mud crab culture has been practiced through ages as an incidental crop in the traditional shrimp farming system, monoculture of mud crab started only after the live mud crab exports had started in early 1990s (Nasar and Noble 1995). Cultivation of mud crab, is largely limited to the 'fattening' (improvement of meat quality), and farming using wild caught seed crabs (200-300 g). The mud crab, *Scylla serrata*, had previously been reported as *S. tranquebarica* until CIBA, and later RGCA confirmed that Indian species, which was formerly reported as *S. tranquebarica* is *S. serrata*.

Among the two species reported in India, *Scylla serrata* has received the highest aquaculture potential, and widely culture cultured species, although both species fetches highest market value. This is due to the highest growth potential of *S. serrate*. However, gravid females of *S. olivacea* has a premium price in the market. ICAR-CIBA has developed a small scale hatchery production technology that can be up scaled at commercial level. As hatchery phase of mud crab is longer than the penaeid shrimps, and fragile nature of the final/post larva, a nursery phase is essential prerequisite for the development of mud crab aquaculture.

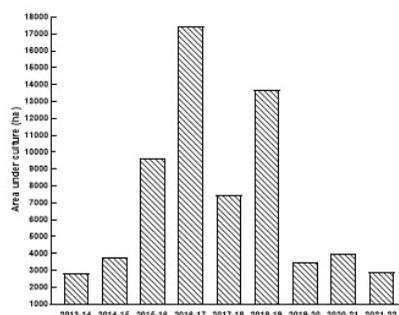
Status of mud crab farming

Aquaculture of mud crab in India, is extensive and not organized as shrimp farming. The last 10 years production data of mud crab indicates that production or area of farming is not consistent. During the last one decade the highest production occurred in 2016-17 with a production of 4408 mt. During this period farming area

under culture was also highest (17478 ha). Although experimental data indicates an average production of 2000 kg/ha, over all productivity is found to be less than 1000 kg/ha in most of the years. However, the last two years of data indicates the productivity is slightly above 1000 kg/ha.



Aquaculture of mud crab production in India



Area under mud crab farming (ha)

Grow out production system

Although mud crab culture is highly remunerative, long culture duration (6-8 months), low survival rate and lower revenue compared to shrimp culture results in reluctance of the farmers to take up this farming practice. Hence, in an effort to circumvent the long culture period and optimize the economics of farming, ICAR-CIBA has developed a three tier modular farming system for mud crab which consists of nursery rearing, pre grow out rearing and finally grow out rearing. Apart from the three tier modular farming, CIBA has also developed a package of practices for polyculture of mud crabs with finfishes, Integrated multi-trophic aquaculture systems and mono-sex culture. Demonstration trials revealed that these farming systems has steadily been adopted by mud crab farmers and found to be economically viable.

Nursery rearing of megalopa

Nursery culture is essential intermediate culture practice in mud crab farming. Several types of nursery rearing has been practiced. Megalopa 3-4 days old (obtained after 20-21 days of larval rearing) can be reared to crab stage in fiberglass (FRP) or cement tanks in the indoor hatchery or in hapas (net cages) erected in ponds.

Nursery rearing in tanks (Indoor system)

Nursery rearing is performed in 1 to 5 t FRP tanks. Megalopa 3-4 days is stocked to FRP tanks at 1-2 ind./L Polypropylene (PP) shade nets (black or green) are cut to 30 cm × 30 cm pieces and a pebble is tied to its centre in order to form structures with

flower like resemblance. These structures are added to nursery tanks as a refuge (shelter) for the larvae to minimize cannibalism. PP strips (60 cm × 10 cm) that float or stay in column are also stocked to the tanks to reduce cannibalism. Megalopa are fed on Artemia biomass (TL: 4-6 mm, 7-8 days old) twice daily. Alternately megalopa may be fed on minced clam meat (*Meretrix meretrix*) at 100% of biomass in two feeding sessions. Water exchange during nursery rearing is carried out at 30% and 50% on a daily basis for megalopa fed on artemia biomass and clam meat respectively. Juvenile crab (BW: 0.3–0.5 g, CW: 5–10 mm), are harvested following 15 days of nursery rearing in tanks and an average survival of 25 – 40% is realized in this system.

Nursery rearing of megalopa in ponds and hapas

Nursery rearing of megalopa is carried out in both tide fed and embankment ponds wherein salinity regime falls within 20-34 ppt. Megalopa can also be reared in mangrove regions or tidal mud flats wherein a minimum water depth of 0.7 m is obtained. Ponds are fertilized using a mixture of organic and inorganic fertilizers 7-10 days prior to stocking of megalopa to generate a sufficient algal bloom and zooplankton population in the pond. Optimal salinity during nursery rearing of megalopa in ponds is 24-28 ppt. Water depth in the pond is maintained at 1.2 to 1.5 m.

Polyethylene (PE) hapas (Net cages: 2m × 1m × 1m) of mesh size 0.5 to 1.0 mm are installed in earthen ponds by tying them to Casuarina or bamboo poles driven to the pond bottom using PP ropes. Hapas are tied such that bottom panel are kept 20 cm above the pond bottom and a free board of 20-30 cm is maintained above water level. Hapas with top panel are preferred over open hapas. Live seaweed (*Gracilaria* sp.) is stocked to the hapas (3-5 Kg) as refuge for larvae to reduce cannibalism. 3-4 days old megalopa (4-6 mg) is acclimated to target salinity (2-4 hours) within the indoor hatchery and stocked to the hapas at 500 ind./m² (1000 ind./L) during evening hours. Megalopa are fed on minced clam meat at 200% of biomass in four equal feeding sessions in the day (0800, 1300, 1500, 1800).

Artemia biomass is also fed to the larvae for the first three days at 5 nos per megalopa. Water exchange in the pond is carried out at 30% on a weekly basis. Crab instar (BW: 0.3–0.5 g, CW: 5–10 mm) are harvested following 15 days of nursery rearing and survival rate of 50-60% is generally obtained. Since megalopa are stocked at high densities, rearing beyond 15 days would result in increased cannibalism and reduction in survival rates. High density rearing of megalopa may therefore be carried out when the objective of the process is to generate crab instar in large numbers for supply to farmers.

Grow out: Rearing of juvenile crabs to marketable sized crabs

Farm design: Rectangular ponds with a size ranging from 250 m² to 10,000 m² (1 ha) area is suitable for mud crab pond construction. Essentially, any shrimp farm can be modified into mud crab farm. Although mud crabs are found to tolerate wide range of salinity from 0 ppt to 40 ppt, salinity above 34 ppt and below 10 ppt are found to be less suitable for pond culture. If there is a probability to enhance salinity above the optimum level in summer months, it is recommended to reduce the salinity by diluting with fresh water. However according to regulations of Coastal Aquaculture Authority it is not acceptable.

The crab ponds should have a minimum water depth of 1 m and further, each pond should have ~12 earthen mounts (~ 5 m³). The top surface of these mounts should be above the water surface (Fig 4). These mounts are breathing space for crabs when dissolved oxygen level of ponds drops below the optimum level. The ponds must be fenced with nylon netting to prevent the escape of crabs, and it should be extending minimum 50 cm above the water line. Further, a strip of plastic should be installed over the fence (about 30 cm width). The lower side of the netting is embedded 10 cm below the base of enclosure.



Fig. Mudcrab growout system showing earthen mounts and hideouts (arrows)

Pond preparation: Pond preparation strategies generally employed in shrimp/prawn aquaculture can also be adopted in mud crab aquaculture. However, it is generally believed that meticulous and stringent pond preparation is not required. The installations like net fencing, earthen mounts should be considered. Pond should be drained and keep it for 1 week. If it is not drainable pond, the pest should be eradicated by applying tea seed cake or powder (15 to 30 ppm).

The procedure adopted by farmers for pond preparation is not available as in the case of shrimp aquaculture. Here we provide a protocol used by SEAFDEC researchers in their experimental culture (Trino et al., 2004). It can be modified according to the site and location of the farm. Liming and fertilization is the best way

to increase the natural productivity of pond. Liming enhance the general health of the pond ecosystem. There are several types of liming material, and most common being agricultural lime stone, burnt lime and hydrated lime. Of these, agricultural lime is found to be best, and it can be applied at the rate of 1 mt per ha. Inorganic fertilizers are applied to increase the phytoplankton productivity in shrimp aquaculture ponds; however, the utility of fertilization in crab aquaculture is not evaluated. It is however essential when crab aquaculture is integrated with seaweed culture. Fertilization with urea at the rate of 25 kg/ha and ammonium phosphate at the rate of 50 kg/ha is recommended.

Transportation and stocking: Farmers of mud crab rely on small crabs or juveniles (25-50 g) sourced from inter tidal flats, estuaries and mangrove to stock grow-out ponds. Handling, packing and transport activities are stress to animals. Nevertheless, crab juveniles are relatively easy to transport by using cane basket, carton lined with moist sea weeds or mangrove leaves (Fig.). Chelae are tied to prevent fighting among crabs. In air, mud crabs have a life span of 2-18 days when packed with moist marine algae, cotton or wood shavings (Vasudeo and Kewalramani, 1960). Stocking should be done with seeds having intact appendages, and without injury, and further seeds should be at uniform size. Differential size leads to cannibalism. Seeds should be stocked when water temperature is low; early morning or late evening preferably night.



Fig. Transportation of Mud crab in live condition

Stocking density in mud crab culture is generally far less than the shrimp farming. The stocking density has a major effect on crab growth, survival and production, and it is generally ranged between 0.5 and 3 crabs/m². Several experiments were

carried out to assess the optimum stocking density in mud crab aquaculture. Trino et al (1999) from Philippines compared the effect of three levels of stocking density (0.5, 1.5, and 3.0 crabs/ m²) on the growth performance of mixed species of mud crabs, *Scylla serrata* and *Scylla tranquebarica* (larger forms). Although there was no significant difference in the growth rate among different stocking density groups, highest harvest size, survival and efficient FCR were significantly higher at the lowest stocking density, and they concluded that mud crab culture at 0.5 and 1.5 crabs/ m² is economically viable. Growth of *Scylla serrata* reared in the farmers pond at Kakdwip centre of ICAR-CIBA was depicted in Fig.

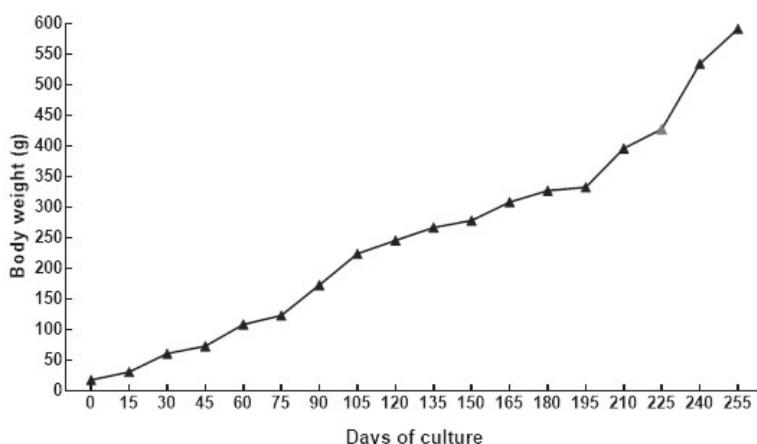


Fig. Growth of *Scylla serrata* reared in the farmers pond at Kakdwip (Christina 2017, CIBA Annual report)

Nutrition and feeding

Despite the growing interest of mud crab aquaculture, formulated diets for grow-out mud crabs have yet to be available, although research institutes like CIBA and CMFRI are at the various stages of commercialization of formulated crab feed. Management of feed is the most crucial element for successful aquaculture as feed is the major input of crustacean aquaculture. Feed accounts for 40 - 50% total operating cost.

Natural diet of mud crab mainly includes crustacea and mollusks, whereas fin fish remnants are found to be very scarce. This is mainly due to the inefficiency of crabs to prey upon the fast moving preys. In the grow out culture management, locally available cheap protein sources (trash fish, mollusks) at the rate of 8-10% of biomass can be given. The crabs can be fed a mixed diet of 25% fish bycatch (trash fish) and 75% fresh flesh of mollusca or crustacea. Crab biomass can be estimated as

the product of mean body weight of stocks in the enclosure and percentage survival. Linear decrease of 5% at every 15 days can be used as an assumed survival. An example for feed calculation is given in the Table. It was reported that better growth for mud crabs obtained when fed with molluscan meat than trash fish, although results are not significant. While comparing the production performance of mud crabs using three different feed treatments, crustaceans, trash fish and without feed, but no significant difference among the treatments. They concluded that endogenous biota of culture system contributes a significant level of nutrition to crab as their data does not show any significant difference fed and unfed pond ponds. They also assumed that feed input may deteriorate the pond conditions of fed pond and it may be the reason for low survival of crabs in these ponds.

Table. Feeding rate in % wet body weight (BW) used throughout the experiment and estimated survival (%) from stocking

	0-30 days	30 - 60 days	60-80 days	Above 90 days
Feeding rate (%)	15	10	7	5
Estimated survival (%)	100	100	70	70

Water quality characteristics

The water depth should be maintained at 80-100 cm level. The water should be replenished regularly, should be exchanged three consecutive days during the spring tide. Generally water should be refreshed at the rate of 40% during the first months, 50% during the second month and 60% during the third month. Water quality characteristics should be monitored regularly. The acceptable optimum level of water quality characteristics are given in the Table. If water quality remains within the optimum level, the water exchange is not required.

Table. The acceptable optimum water quality levels in mud crab grow out ponds

Variables	Range
Temperature (°C)	23 - 33
Transparency (cm)	25 - 45
pH	7.5 - 8.5
Dissolved oxygen (ppm)	>3
Salinity (ppt)	10 - 35
Total alkalinity (ppm)	200

Dissolved inorganic phosphate (ppm)	0.1 – 0.2
Nitrate – N (ppm)	<0.03
Nitrite – N (ppm)	<0.01
Ammonia – N (ppm)	<0.01
Cadmium (ppm)	<0.01
Chromium (ppm)	<0.1
Copper (ppm)	<0.025
Lead (ppm)	<0.1
Mercury (ppm)	<0.0001
Zinc (ppm)	<0.1

Harvest and post-harvest

Culture period is generally 3 to 6 months and is determined mainly by the size at stocking and the preference and demand, existing in the market. Culture period may be restricted to 60 days, if the crabs having a size of about 250 gm are preferred in the market. Culture duration will be 150 days for *S. tranquebarica* from an initial size of 25 g to a harvestable size of 350 – 450 g, if the stocking density is 1 crab per m². To obtain a harvestable size of 800-1000 g the culture has to be extended further up to 7 months. For *Scylla serrata*, culture duration will be 120 days with an initial size of 25 g and harvestable size of 200-300 g if the stocking density will be 1 crab per m². To obtain larger sizes (400-500 g), culture period can be extended to further 3 months. Harvest of crabs can be effectively done in a tide-fed pond by letting in water through the sluice gate into the pond during incoming tide. As the water flushes in, mud crabs tend to swim against the incoming water and congregate near the sluice gate from where they can be caught with the help of a scoop net. Partial harvest can be made with baited lift nets and bamboo cages/traps. To have a total and complete harvest, crabs are to be hand-picked after completely draining the culture pond. Crabs should be tied immediately after their capture in order to curb their movement and to avoid the fighting among themselves and thereby losing their legs. Tying is a process in which a nylon/jute thread is placed in between the frontal portion of the body and the chelipeds and is coiled around their fingers after keeping the chelipeds in folding posture and subsequently both ends of the thread is put into a double knot at the rear end of the crab. The “water crabs” encountered in the final harvest can be utilized for fattening purpose. The tied-up crabs are to be initially washed with fresh sea water and subsequently sent for local marketing after packing them in bamboo baskets, in which, they are kept in layers alternatively with materials such as wet seaweeds or moist wood shavings or cotton soaked with

sea water to keep the crabs in cool and moist condition. Those crabs exported in live condition, are given a fresh sea water dip and packed in perforated thermocoal boxes for air shipment. The expected survival rate during culture would be around 70 to 80 %. Mud crabs are generally sold in live condition for both local consumption and live crab export trade. For the purpose of marketing, the mud crabs are graded as “extra large” (1 kg and above), “large” (500 g to less than 1 kg), “medium” (300 g to less than 500 g) and “small” (200 g to less than 300 g). The female crabs with fully developed ovary are usually sold for a higher price. Live and meaty mud crabs weighing above 300 g are considered for export, while the undersized live crabs (less than 300 g) and those live crabs which have lost their legs are sold in local markets. While marketing, about 20 % mortality is observed when the transport is by sea whereas transport by air reduces the mortality to about 5 to 10 %. Packing in ventilated and insulated containers instead of cardboard boxes, with 95 % relative humidity and 16 - 20°C temperature, will reduce the mortality of the mud crabs during transit up to 7 days and thereby reduce the mortality during transport.

Grow out: fattening of mud crab

There are controversies to include crab fattening as a form of aquaculture. However, historically mud crab aquaculture probably started as crab fattening. It is a way to improve the value of catch by holding them for a short period to improve the marketability. Grow out culture of mud crab in many cases merely fattening of wild crabs in ponds or cages as little as 20 to 30 days. The terminology of fattening has received a confused meaning among public. Fattening is only intended to allow crabs to develop firm flesh and hardened shells. In some cases to produce egg crabs; here female crabs that show early signs of gonad development are held until the gonad get matured. Essentially fattening improves the quality of crab meat and in turn the marketability of the products.

Description of farming

General farming practices are identical to the grow-out based on juvenile crabs except in the culture duration and size characteristics of the stocking material. Recently molted crabs that are unacceptable to the export market are used as ‘seed’ for stocking. The pond enclosures are smaller than the juvenile rearing ponds (100-200 m²). However pond netting and fencing are essentially identical to juvenile based grow-out system. The animals are fed with molluscan or fish by catch at the rate of 5-10% of biomass. Water is replenished once in 15 days depending on the availability of water source. Selective harvesting is carried out, and thus, fattening program is continuous throughout the year. Performance of mud crab reared for one month in Chilka lagoon is given in the Table.

Table. Summary of the experimental fattening of mud crab conducted in Chilka lagoon, Orissa

<i>Parameter</i>	<i>Value</i>
No of crabs stoked	61
No recovered	52
Mean initial weight (g)	519
Mean final weight (g)	529
Mean percent weight gain	2

Pond fattening is found to be economically viable aquaculture form throughout the regions where it is being operated. After pond fattening, the market price of the crab increases to at least Rs 100-110 per kg. Taking an average price of Rs 110 and 230 per Kg for water and fattened crabs, respectively, indicates the gross profit per kg of crabs harvested is about 110%.

Polyculture system

Polyculture is a sustainable farming practice where combination of two or more complementary species, with different feeding habitats effectively utilizes nutrients resulting in higher production compared to monoculture of a single species. In India, traditional brackishwater polyculture is carried out in large tide-fled impoundments where auto-stocked fish, shrimp or crabs are reared for a period of 6–7 months with a production up to 500 kg/ ha (Lovatelli, 1990). Though shrimp were an integral part of polyculture farms, farmers no longer prefer shrimp in such systems as outbreak of white spot viral disease in shrimp culture demands high biosecurity, with minimum or zero-water exchange which these traditional systems cannot meet. Thus, culture of shrimp in polyculture farms started losing its popularity in low-lying brackish water areas where tide-fled farming systems are mainly practiced. In these areas, mud crabs form an economically viable alternative crop for diversification.

Our experimental polyculture trial (210 days) of mud crabs with finfish like grey mullets and milk fishes wherein both animals were stocked at 1.5 no./m² resulted in a total productivity of 4,533 and 3,694 kg/ha in which mud crab accounted for 53.69% and 60.56% of the total productivity. In polyculture farming finfish were fed floating pellet at 2–3% of BW and mud crabs were fed fresh and farm made feed at 5–8% of BW. Among finfish, *M. cephalus* attained highest final body weight, 241.55 ± 26.44 g followed by milkfish, 200.46 ± 11.82 g and mud crabs attained 400-420 g. The economic analysis indicated benefit–cost ratio (BCR) of 1.57 and 1.73 in T1 and T2 respectively with 10% and 35% insignificant increase ($p > 0.05$) in BCR and profit per kg, respectively, in T2 compared with T1.

Box culture

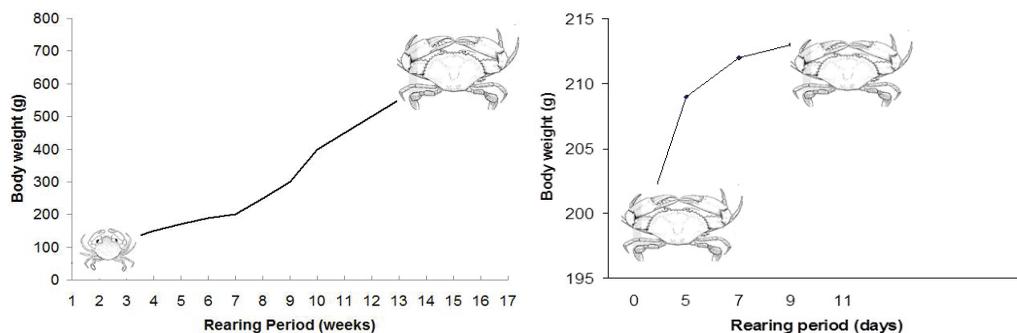
In recent years, a capital-intensive box-culture method of production has gained popularity among mud crab farmers. In box-cage system, fattening is largely carried out although grow-out is also done in a lesser scale. In case of grow-out culture, the nursery reared crab are stocked in boxes at the rate of one crab per box and reared for 4-6 months. Box-culture system has both its advantages and disadvantages. The pros of the system include lower maintenance, predictability, easy assessment etc. A high capital investment on boxes and related equipment is one of the drawbacks of box-culture system. The lower activity of crab is also believed to lower the metabolism of mud crab and subsequent feed intake. The animals in boxes are fed ad libitum only once daily with trash fish compared to two times feeding in open pond culture system. The animals demonstrate very low activity inside the box-cage system and with constant exposure to sunlight on the surface, infestation by algae and issues with molting can constitute a problem during culture. Crab fattening involves rearing of soft-shelled or immature crabs in individual boxes wherein the animals are fed until the shell hardens or the gonads are fully developed and fill the mantle cavity. Gravid female with full orange-red ovary fetch a higher price both in domestic and export markets. A 200 g soft shell animal may gain 25-50 g weight during fattening operation and the fattening may continue for 9-10 months in a year with each fattening cycle duration of 20-30 days.

Submersible box system

The high temperature during summer induces stress to mud crab cultured in boxes which remain afloat at the pond surface throughout the day. Besides the stress caused by the heat, the constant exposure to sun may cause algal growth and fouling on the exoskeleton. This, in extreme case may lower the market value of the animal, hinder molting and death due to high temperature. A practical and innovative thinking is imperative in solving a problem faced in the farm, and has been one of the significant factors in improving culture system. This submersible box-system has been engineered and works by virtue of a pumping system. In this system, the PVC pipe which help float the box are interconnected and a pump is attached in one corner of the pipe. The system functions by pumping in or flushing out water from the pipe which submerge or float the structure respectively. The whole structure is mostly submerged and lifted to the surface during feeding.

Mono-sex culture: Owing to the obvious size dimorphism in mud crab, it is believed that mono-sex culture of males would be more profitable than conventional mixed culture. In mud crabs, males are larger than the females. Mono-sex female, mono-sex male and mixed sex culture were evaluated. After 143 days of culture, the highest average body weight was attained in crabs reared in mixed sex ratio, followed by

mono sex female culture. The survival was higher in the mono-sex female culture, followed by mixed culture.



Diagrammatic representation of two forms of grow out culture (A) rearing from juvenile to marketable size and B) fattening of adult crab; note that size variation is not occurred in this form of rearing.

Summary of economics of mud crab farming (assumptions: pond size=1 ha; stocking density 0.5 crab/m², Period of culture: 10 months; Survival: 40%) is given in the Table.

Table. Economics realized for 10 months culture including nursery and mid grow out and final production.

No	Item	Amount (Rs)
1	Capital expenditure (including lease charge, pond dyke construction, fencing)	250000
2	Recurring expenditure	
	a) Eradication	6000
	b) Lime and fertilizerts	6000
	c) seed cost (for 5000 crab let per 6 per animal	30000
	d) Transportation charges	5000
	e) feed (fresh feed, trash fish; total 9000 kg; Rs 20 per kg	180000
	f) fuel and miscellaneous	5000
	g) wages (for 10 months Rs 8000 per month	80000

No	Item	Amount (Rs)
	h)Sub total	312000
	i) Total expenditure(1+h)	562000
3	Production (kg)	2000
4	Gross income (Rs 800 per Kg)	16,00,000
5	Net profit (4-I)	10,38,000
6	Benefit-cost ratio	1.84697509

Conclusion

Aquaculture is generally equated with the intensive salmon culture and penaeid shrimp aquaculture. These culture practices are generally technology driven practices, however there are aquaculture systems which can support the poverty alleviation program and can popularize through participatory approach. The mud crab aquaculture is one of the best forms of rural aquaculture which has the economy of potential for improving the rural villages. Presently crab aquaculture is predominated by raising wild caught juveniles to marketable size. Although there are several disadvantages in this form of aquaculture, for example, variability in number of animals to be utilized for grow out, no scope for further sophistication and potential effects on ecosystem stemming from mortality of bycatch and removal of prey from the food chain, mud crab farming is relevant and useful at least as a transient link between small scale aquaculture and industrialized aquaculture. The advantages of mud crab farming based on wild caught juveniles are manifold: availability of seed stock, which is naturally selected, less occurrence of disease and further broader economic benefits including the opportunities for coastal dwellers in developing countries. In addition, responsible capture and culture of wild juveniles improves the fishery of target species by circumventing the high rate of natural mortality associated with settlement of post larvae.

PROSPECTS OF FINFISH FARMING THROUGH SPECIES DIVERSIFICATION FOR SUSTAINABLE DEVELOPMENT IN BRACKISHWATER AQUACULTURE

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Introduction

Brackishwater aquaculture has been an age old practice in the traditional culture systems of India in the form of traditional prawn filtration systems *Pokkali* fields of Kerala, the *bheris* of West-Bengal, *Gheris* of Orissa, *Khar* lands of Karnataka and *Ghazni* fields of Goa. As early as 1911 James Hornell suggested the development of salt water fish farming in Madras Presidency which led to establishment of marine fish farm near Tuticorin by utilizing few lagoons in the area and stocking mullets and sand whiting (*Mugil spp.* and *Sillago sp.*). The prime brackishwater finfish species having high consumer preference and market demand in India include Asian seabass *Lates calcarifer* (Bloch, 1790), grey mullet *Mugil cephalus* (Linnaeus, 1758), milkfish *Chanos chanos* (Forsskal, 1775), pearlspot *Etroplus suratensis* (Bloch 1790), and red snapper *Lutjanus argentimaculatus*. In the year 1997, a significant milestone was achieved with respect to brackishwater finfish aquaculture in our country through the successful breeding of Asian seabass in captivity, at the Central Institute of Brackishwater Aquaculture. The R&D in seabass breeding thus led to the establishment of the first brackishwater/ marine finfish hatchery of our country located at Muttukadu Experimental Station (MES), CIBA, Chennai.

Subsequently seabass hatching and rearing technology, developed by CIBA was transferred to the Rajiv Gandhi Centre for Aquaculture (RGCA) during 1999-2000 (CIBA Annual Report 2000-01). The hatchery produced seeds are being produced and supplied to the farmers, which is further spreading seabass farming in the country. The demand for hatchery produced seeds of seabass is on the rise, reflecting the increasing interest of brackishwater farmers in adopting seabass nursery rearing and farming technology. The year 2015 will go down in the history of Indian brackishwater aquaculture for another significant milestone achieved through the first successful captive breeding of marine herbivorous fish species, the milkfish *Chanos chanos* by ICAR-CIBA. The herbivorous species forms the mainstay of brackishwater finfish aquaculture of south-east Asian countries such as Indonesia and Philippines. Captive

breeding followed by successful larval rearing and fry/fingerling production helped to conduct scientific milkfish farming in India. Successful results came from the efforts for transporting the batches of fertilized eggs of milkfish to private entrepreneurs and the subsequent rearing of milkfish larvae to fry stage and its sale to growout farmers. CIBA has been successful in breeding and developing farming models of the catfish *Mystus gulio* which commands good market price in the states such as West Bengal.

The declaration of pearlspot, “Karimeen” as the state fish of Kerala in 2010 came as a boon to this indigenous cichlid which has been an important brackishwater food fish of Kerala, with great local demand the a market price is in the range of Rs. 300 to 600/kg. Grey mullet *Mugil cephalus* by virtue of occupying lower trophic levels in the food chain and at the same time having a high market value is a species of significance for sustainable aquaculture systems like the IMTA (Integrated Multi-trophic Aquaculture) and finfish polyculture. We are still reliant on wild seed resources for its aquaculture and its availability is getting limited due to deteriorating nursing grounds and emerging regulations imposed on wild seed collection by states like Kerala. Hence, ICAR-CIBA has laid high impetus on developing a technology for grey mullet captive seed production. Brackishwater ornamental aquaculture is also given a special focus and being developed as new area on account of its potential to play a significant role in providing livelihood to small scale farmers and Self Help Group’s, by adopting the homestead rearing model. CIBA has bred spotted scat, *Scatophagus argus*, Moon fish *Monodactylus argenteus* for the first time in the country. Species such as orange chromide, crescent perch, pearlspot are also being developed as ornamental fish production models, suitable to get regular monthly incomes to farmers and SHGs.

Brackishwater finfish species seed production

1.1 Asian seabass, *Lates calcarifer*

Asian seabass is an important food fish in Indo-pacific region, most sought after candidate species for aquaculture in recent years and it has expanded as a candidate species for cage culture and in the recirculating aquaculture systems globally. Asian seabass *Lates calcarifer* is an euryhaline fish belongs to the family Centropomidae widely distributed in the Indo-West Pacific region, Arabian Gulf to China, Taiwan Province of China, Papua New Guinea and northern Australia. It is found throughout the northern part of Asia Southward, Queensland (Australia) West ward to East Africa ((Copland and Grey1987).



Lates calcarifer is known as seabass in Asia and Barramundi in Australia and it has also been variously called as 'bhetki' in India. For the first time in India, seabass was bred in captivity and successful larval rearing was done in 1997 which paved way for the large scale seed production and culture of seabass in India followed by year-round seed production by establishing recirculation aquaculture systems. Hatchery production of seabass involves breeding of captive broodstock fish, rear fish larvae up to fingerling size with weaning feed. The hatchery technology includes, broodstock development, management, maturation, breeding, larval rearing, live feed culture and nursery rearing. Asian seabass is catadromous fish, grows in coastal low saline area migrate to sea for spawning, in the Sea many influential factor induces maturation and spawning process naturally. In captive broodstock, many times marine conditions may not prevail, hence we have to induce the maturation and spawning. The exogenous hormones are used to induce the maturation and spawning. In CIBA, Luteinizing Hormone Releasing Hormone – analogue (LHRH-a) being used for maturation and spawning. For induction of maturation in the broodstock fishes reared for more than two years in the case of males and 3 years in females, if found not matured, the hormonal pellet prepared with LHRH-a @50-100µg/kg was implanted to prolong the gamete formation.

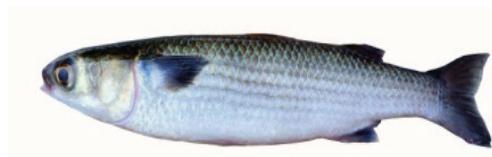
1.2. Milkfish, *Chanos chanos*

Milkfish (*Chanos chanos*) is one of the most popular cultivable brackishwater finfishes in the south east Asian countries and widely distributed in the Indo-Pacific region. The maximum weight and age of this fish were reported as 14kg and 15 years respectively. In India, it is named as *Paal Meen* in Tamil, *Pala Bontha* and *Tulli Chepa* in Telugu, *Poomeen* in Malayalam, *Hoomeenu* in Kannada, *Golsi* in Goa and *Seba khainga* in Oriya. Being herbivore, milkfish feeds on plankton, benthic algae, detritus matter in the natural condition and easily accepts the pellet feed under culture conditions. It can tolerate and live in extreme salinity ranging from 0-100 ppt but growth is optimal between 0.5-40 ppt. Milkfish can attain the table size weight from 400 to 500 gm in 5-6 months under culture conditions. Milkfish having tiny bones resemble with Hilsa and can be considered as a '*Deccan Hilsa*'. Milkfish can be produced in the farm with the production cost of Rs.80-90/kg by feeding with low protein pellet feed.



ICAR-CIBA has made major breakthrough on captive breeding of milkfish for the first time in India during June 2015 and developed comprehensive technology package for seed production of milkfish. Captive breeding of milkfish involves development of land based captive broodstocks (6+ years old) and application of calculated dose of slow release hormone (LHRH-A) pellet. Hatchery produced seeds were distributed among farmers for promotion and demonstration of milkfish farming in coastal states. To educate the farmer community about this technology need-based trainings are being organized by ICAR-CIBA .

1.3. Grey mullet, *Mugil cephalus*



Mugil cephalus L. is cosmopolitan and contribute significantly to the economy of countries of Southeast Asia, Mediterranean region, Taiwan, Japan and Hawaii. This species is euryhaline and capable of surviving in wide variety of marine, estuarine and freshwater environments of varying turbidity, salinity and dissolved oxygen levels (Thomson 1955, Ibanez and Guitierrez-Benitez 2004).

The species is recognised economically as an important food fish. The roe of the species is used to prepare "Bortaga cavier" a delicacy in Taiwan and Japan and hence referred to as "Grey gold". In India grey mullet has good market in all the coastal states fetching between Rs 300-400 per kg. Grey mullet is situated at the base of the food chain and feeds on detritus and benthic micro-algae, thus playing its significant ecological role as a converter of primary productivity, particulate organic matter and detritus into quality fish protein. The significant market demand, tolerance to wide salinity ranges and ability to utilise the herbivorous and detrital food chain qualifies it as an excellent candidate species for aquaculture. A quality broodstock forms the foundation for a breeding programme. Being a high value herbivorous species, grey mullet has high potential to contribute to the brackishwater aquaculture production.

Considering the economic significance of the grey mullet, the major constraints affecting its development has to be addressed scientifically, especially with respect to seed production.

ICAR-CIBA has also initiated captive seed production of grey mullet seeds are being produced at the fish hatchery of CIBA experimentally for the past three years during the annual breeding period. Few interested farmers were supplied with seeds for farming. Males of grey mullets mature between 250- 300 mm standard length while females mature at slightly larger size, 270- 350 mm. Males are reported to mature at approximately 2-3 years of size while females mature at 3-4 years. The stage of maturity in female fish is assessed by biopsy of the oocytes. This helps in judging the right stage of maturity and giving the appropriate hormonal treatment. Captive grey mullets found to possess an oocyte size about 80-90 μm were found to be in the primary oocyte stage, 110-120 μm in the slightly advanced stage of the primary oocyte, the perinuclear stage. Oocytes in the size range of 140- 150 μm were found to be in the cortical alveoli stage. Further, oocytes above 180 μm were seen to be vitellogenic. This stage is good for administering LHRHa implants for supporting oocyte development to functional maturity. In grey mullets, an ova diameter of 600 micro-m is reported to be optimum for successful induced spawning.

1.4. Mangrove red snapper, *Lutjanus argentimaculatus*

Mangrove Red Snapper *Lutjanus argentimaculatus* is an Indo-Pacific species that inhabits riverine, coastal and offshore reef habits. Juveniles and young adults found in mangrove estuaries and in the lower reaches of freshwater streams. They migrate offshore to deeper reef areas, sometimes penetrating to depths in excess of 100 m. The fish has greenish-brown to reddish body. Fishes that are found in deeper water have reddish body colour. Young fishes have eight whitish bars on the sides and 1-2 blue lines across the cheek. *L. argentimaculatus* has a slightly concave caudal fin and the scale rows on the back are roughly parallel to the lateral line. Habitat frequently consists of areas of abundant shelter in the form of caves or overhanging ledges. It feeds mainly on fishes and crustaceans. *L. argentimaculatus* is an important food and sport fish throughout the Indo-Pacific region, but never found in large quantities. They caught mainly with hand lines, bottom longlines and trawls. Aquaculture importance of this species has been well documented due to high demand in the international market.



L. argentimaculatus can attain the maturity under pond/tank/cage based captive conditions when they maintained in the salinity regime of above 30 ppt. The fish can be induced to spawn through hormone (hCG) treatment. *Lutjanus* are broadcast spawner. Batch fecundity of this species estimated was around 5.0 lakh eggs/kg body weight. The size at first maturity for male and females reported were 2.5 and 3.9 kg respectively. The fertilized eggs size would be around 750 μ m and the newly hatched larvae size were between 1.6-1.75 mm. The larvae can reach to 2.0 cm fry size at 40 day post hatch by feeding with live feed such as rotifer, *Artemia* nauplii and followed by the artificial feeds.

1.5. Pearlsplit, *Etroplus suratensis*

Pearlsplit, *Etroplus suratensis*, is a high value food fish popular in different coastal states of India; it is also finding market as an ornamental fish. Pearlsplit is distributed in peninsular India and Sri Lanka. Its tolerance to wide range of salinities makes aquaculture of the species possible in both freshwaters and brackishwater bodies.



Being omnivorous in nature, aquaculture of pearlsplit is relatively simple, economical and especially suitable for small scale aquaculture for supporting livelihood of fish-farmers. Pearlsplit is extensively farmed in brackishwaters of Kerala has shown productions upto 1t/ha when cultured along with milkfish and mullets (George, 1971). Traditionally pearlsplit has been cultured in pokkali fields of

Kerala along with other brackishwater fishes. Pearlspace has chiefly been cultured by farmers as a component of polyculture in brackishwater systems. Small scale cage based aquaculture experiments showed that stocking pearlspace @ 200 nos m³ in 2 m net cages can give a production of 26 kg/ m³ in 200-260 days using commercial feed (crude protein-20%). More recently, with the support of the state fisheries department many farmers and Self-Help Groups (SHG's) in Kerala are involved in culture of pearlspace in small cages (2-3 m³) and pond systems. However, one of the major limiting factors for expansion of pearlspace aquaculture is inadequate availability of seed for stocking in different culture systems. Pearlspace exhibits a high degree of parental care and has very low fecundity as compared to other brackishwater fishes are the main reasons which makes mass scale seed production of the fish challenging. Hence development of technologies which allow seed production at multiple locations in the form of backyard hatcheries or small scale seed production systems is important. However, the fish is easier to breed compared to many other brackishwater fish and today different models in a range of systems are available or being tested, so that seed production can be achieved by entrepreneurs, Self- Help Groups or farmers themselves depending on their local resources.

1.6. Long whisker catfish, *Mystus gulio*

The long whiskers catfish, *Mystus gulio* (Hamilton, 1822), belongs to the family Bagridae is a euryhaline fish, which is commonly called as nona tengra in Bengali (Kumar et al., 2019). *M. gulio* is commercially important estuarine catfish of Sunderban delta of Bangladesh and India. It has also market value in state of Andhra Pradesh and Odisha. It is a small indigenous fish species (SIS), having high nutritional value (Ross et al., 2003). The domestic market price of *M. gulio* is very high and ranges from 200-700 Kg⁻¹. The important attributes such as high nutritional value, consumer demand, high market price, hardy nature and faster growth make this species a desirable candidate species for aquaculture in Southeast Asia. Due to euryhaline nature this fish can be breed and farmed in both fresh and brackishwater environments (Siddiky et al., 2015). This species is suitable for co-cultured with other brackishwater fishes in paddy fields and bheris of the Sunderban. This fish can also be farmed at high densities in cages and Recirculatory Aquaculture System (RAS). Expansion of *M. gulio* is stumbled because of the non-availability of large quantities of hatchery produced seeds. In this connection, Kakdwip Research Centre of ICAR-Central Institute of Brackishwater Aquaculture, West Bengal, India has developed and popularized a cost effective farmer-friendly seed production and farming technology for *M. gulio*.



During the spawning season, mature *M. gulosus* are collected from the broodstock ponds. An ovarian biopsy of the female is performed to assess maturity. However, without ovarian biopsy, maturity can be judged through morphological observation of vent; a swollen belly and swollen reddish vent indicates maturity. Mature males can be identified by the presence of elongated papillae with a pinkish tip. Generally, female and male in the size range of 60-120 g and 25-75 g, respectively, are selected for breeding. The operational sex ratio of male and female is 2:1. A single intramuscular injection of either human chorionic gonadotropin (hCG), Leutinizing releasing hormone (LHRHa) can be used to induce the fish to spawn.

Brackishwater Finfish aquaculture- The Present Scenario

Asian seabass has been mooted as a prime candidate for diversification to finfish farming on account of its high market demand (Rs.400-600 per kg), and availability of hatchery produced seed and formulated extruded feeds. Globally seabass is cultured in different culture systems like cages, ponds, pens and tanks showing the adaptability of the fish to different culture methods. In India seabass is primarily cultured in brackishwater pond systems, where it exhibits growth rates ranging from 800g-1.0 kg in a period of 6-8 months. Partial harvesting of larger fish is carried out periodically in this extensive farming practice. Monoculture of seabass is practiced at stocking densities of 4000 to 5000 nos/ha⁻¹ (initial wt.-60-80 g) and a production of 3.5 to 4.0 t ha⁻¹ can be achieved. The cost of production is around Rs. 175-225/kg at a fish sale price of Rs 350-400/kg. To develop a holistic model of seabass culture, a formulated seabass feed, 'Seabass^{Plus}' has been developed by CIBA for nursery and growout culture which gives an FCR of around 1: 1.5. Presently, seabass is considered as one of the most potential finfish aquaculture candidates for those looking for diversification from shrimp culture.

Herbivorous species form the backbone of sustainable fish farming models due to the lower cost of production- milkfish, grey mullets and pearlspot have been traditionally cultured by enhancing the ponds natural productivity and through low cost supplementary feeding using agro-by-products. CIBA's effort on the seed production of these fish species bore fruit with the captive breeding of milkfish at its Muttukadu Experimental Station (MES). Today hatchery produced milkfish seeds

distributed to brackishwater farmers across the country are being cultured using growout formulated feeds specially developed for milkfish. Interventions in parental care of pearlspot has assured the enhanced seed production and given rise to a modular tank based system for seed production for adoption by small scale farmers.

Novel finfish farming technologies being given key focus by CIBA

In keeping with its slogan “Brackishwater aquaculture for food, employment and prosperity”, ICAR-CIBA recognizes that brackishwater aquaculture is a powerful tool to bolster the livelihood and nutritional security. Hence, focus has been given by the CIBA to develop location specific need based models for different stakeholders.

- i) **Satellite based nursery rearing of seabass** - One of the interesting innovative approaches adopted by CIBA for developing seabass as a separate livelihood activity is the hapa based nursery rearing model, where hatchery reared fry are cultured for a duration of about 60-75 days to fingerlings size. This model is being mooted both as a livelihood activity for farmers for giving returns in a short duration and also for developing satellite seabass seed rearing centres to facilitate widespread adoption of seabass aquaculture. This helps in saving space and time during the grow-out culture of seabass and helps farmers to tide over the phase which requires physical labour for frequent size grading of the fry. Adoption of nursery rearing of seabass fry by farmers involved in low volume cage culture of Asian seabass *Lates calcarifer* is encouraged by ICAR-CIBA. The activity helps farmers get a better control over the initial size used for stocking in cages, a factor critical for getting optimum survival rates and fish production.
- ii) **Low volume cage culture** - The access of small scale farmers to diverse opportunities offered by different aquaculture initiatives is often limited by ownership or access to water resources, access to simple and adoptable technology and high investment costs. Production of high value fish using low volume cages set in brackishwater bodies can thus be a potential livelihood option to the small scale farmers. Low volume cages can be fabricated by the farmers themselves. Species like seabass stocked at rates of 25 advanced fingerlings/r cubic-m has shown to yield a production upto 20 kg m⁻³. For example, in a demonstration using 3 cage units of 8 m³ each, a production between 450-500 kg of seabass was obtained partial harvest of the fish from the cages can thus provide the family with sustained monthly income of Rs 10,000-15,000 by sale of the fish at Rs 400/kg. Construction and setting up of these low volume cages is also being mooted as a skill development activity for small farmers.

- iii) **Integrated Multi-Trophic Aquaculture (IMTA)** - IMTA is the farming of aquaculture species from different trophic levels and with complimentary ecosystem function. For laying a roadmap for sustainable aquaculture, CIBA is developing economical polyculture models and adopting IMTA (Integrated Multi-Trophic Aquaculture) approach. These models have been successfully demonstrated at Kakwdip, West Bengal and Sindhudurg, Maharashtra with farmers participation. The benefit cost ratio of pond based IMTA was worked out to be 1.5 as compared to 1.4 in monoculture of shrimps at the culture demonstrated at Sindhudurg district of Maharashtra. Culture demonstrations at Kakwdip centre of ICAR-CIBA has shown the environmental and economic benefits of IMTA over conventional culture practices.
- iv) **Finfish seed production from egg stage** - Realizing the need for elaborate investment and infrastructure for maintenance of broodstocks of finfishes, private entrepreneurs are encouraged to transport fertilized eggs for hatching and subsequent larval rearing in their hatcheries. This model has been successfully adopted in case of candidate species like seabass and milkfish by private entrepreneurs.
- v) **Ornamental fish seed rearing as a household activity** - CIBA is mooted the adoption of nursery rearing of ornamental fish like silver moony, spotted scat orange chromide and pearlspot as an activity to be adopted at household levels for getting regular monthly income. As a part of the Mera Gaon Mera Gaurav program of CIBA, pearlspot nursery rearing as a livelihood activity is being successfully adopted by tribal women groups.

Way forward for brackishwater finfish aquaculture development and CIBA's interventions

ICAR - CIBA has placed a major thrust on developing economically viable seed production technologies of the prime brackishwater candidate species. The developments of hatchery technologies are also being followed by partnership with entrepreneurs for facilitating technology adoption in different states under PPP mode. This is witnessed in the partnerships both for shrimp and finfish species. There is a need for establishing private sector hatcheries for scaling up of seed production to cater the increasing demand of fish seed among brackishwater fish farmers. For the development of large scale economical finfish aquaculture practices, development of efficient, eco-friendly and low cost feeds is perceived as the next major challenge. CIBA has developed feeds for Asian seabass and other major species are being tested. By entering into partnerships, CIBA is also facilitating the development of feed mills and developing feeds for different brackishwater food

fish and ornamental species. Considering the significance of aquaculture as a tool to alleviate poverty, provide livelihood and nutritional security, CIBA lays a major thrust on developing family farming models for widespread adoption in different states. Thrust is also being laid for developing suitable marketing models for getting the best price for the farm produce.

The aquaculture sector in the inland saline waters needs an ecological mapping of salt affected areas (including salinity, composition) for development of region-specific aquaculture practices. Introduction of low-cost, low-risk species for sustainable development of inland saline water aquaculture, with special reference to small and marginal farmers is need of the hour. Establishment of a National Aquaculture Network and Public Private Partnerships (PPP) is essential to ensure the supply of inputs like seed, feed and support for marketing, processing and exports to non-coastal states. Development of production skills and farming clusters, promoting support groups, cooperatives and contractual farming under strict biosecurity monitoring and regulatory governance for the development of brackishwater finfish aquaculture need to be prioritized in the inland saline areas. ICAR - CIBA visualizes and strives for a holistic sustainable development of the brackishwater aquaculture sector of India with an underlying thrust on sustainability, economic viability and livelihood provision. For this ICAR -CIBA reaches out for active partnerships with the state governments, private sector, research organizations and Self-Help-Groups to develop and advance the brackishwater aquaculture technologies for the betterment of the farming sector. Species diversification in aquaculture and developing need based, location specific technologies is the best roadmap for sustainable brackishwater aquaculture sector for our country.

THE ECONOMICS OF SHRIMP CROP INSURANCE IN INDIA: FARMERS & INSURERS PERCEPTION AND PRODUCT GAP ANALYSIS

T.Ravisankar, R.Geetha and C.V.Sairam

Structure of shrimp production and export in India

Aquaculture produces more than eight lakh tons of shrimp in India in the last couple of years. Three major species viz., white shrimp (*Penaeus vannamei*, 96% production), tiger shrimp (*Penaeus monodon*), and freshwater prawn (*Macrobrachium rosenbergii*) form the major portion of shrimp production in India. More than 1.6 lakh ha area is under shrimp culture in remote coastal rural areas. More than a million people are employed in areas of limited entrepreneurial avenues.

Shrimp is the 2nd largest foreign exchange earner next to basmati rice exports. Indian shrimp exports during 2022-23 was 7.11 lakh tonnes. India has earned Rs. 43,136 crores in 2022-23 from shrimp exports, which was only Rs. 4182 crores in 2009-10 i.e., shrimp production has increased by nine times in 14 years - which explains the overall profitability, growth and stability of shrimp culture. Advances in the scientific technology coupled with stringent regulations imposed on aquaculture have made this giant leap possible. Though export market performance is mostly based on trade relations and trade balances, USA (39%), China (20.5%), Europe (13.4%) and Middle East along with Vietnam are our important export destinations. Our domestic market also consumes 70,000 to 100000 tons, mostly sold by farmers who do multiple harvests from 100 counts and sometimes from distress harvests on incidence of diseases.

The top six countries of global shrimp production by volume are Ecuador, India, China, Vietnam, Indonesia and Thailand. Major shrimp consumption centres are the United States, Europe- Spain and France, China and Japan. The present production and consumption pattern makes the south and east parts of globe producing shrimp for meeting the demand of affluent western countries.

Though India is one among the major shrimp producer and exporter for the last few decades, introduction of exotic SPF vannamei has put indian shrimp farmers in an advantageous position due to the availability of SPF (Specific pathogen free) seeds, development of Better Management Practices and Bio security protocols, production of high volume and easy marketability of vannamei shrimp. Apart from

the above, farmers venture into nursery farming, bio-floc based farming and lined ponds for better control and management of shrimp production.

Vannamei shrimp constitutes the bulk of Indian shrimp export. Andhra Pradesh is the largest shrimp producing state (Table). Majority of the aquaculture farmers are small farmers, own 2-3 ponds and face huge obstacles to raise working capital for the crop, due to lack of access to institutional credit and insurance. The loss of one crop due to natural calamities or viral diseases make the farmers fall into deep debts as they are to repay the loans taken for the crop and also raise money for next crop season.

Table. Total shrimp (Tiger, *P. vannamei* & Scampi) production in India during 2020-21

S. No	State	Area Utilized	Production (Mt)	Productivity t/ha
1	Andhra Pradesh	74512	639896	8588
2	Gujarat	9021	50526	5601
3	Tamil Nadu	8630	44816	5193
4	West Bengal	50844	54582	1074
5	Orissa	11200	44555	3978
6	Maharashtra	3145	3185	1013
7	Karnataka &Goa	3145	3185	1013
8	Kerala	2971	1868	629
	Total	166722	843633	5060

Insurance operation across the shrimp value chain

The insurance and government support across the shrimp value chain is depicted in Table 2. Shrimp aquaculture is labelled as “risky venture” by the finance professionals and due to this, credit and insurance institutions are cautious to take up business in shrimp crop sector. Everyone from input supply systems to shrimp consumers, different options for availing insurance cover and government or institutional support system are provided. Only shrimp farmers lack crop insurance or any direct government support in India.

The NFDB has proposed to subsidize the insurance premium to certain extent, and the scheme is yet to reach all the farmers in practice. Though a couple of insurance companies have aquaculture crop insurance schemes in their kitty of insurance products, the extent of actual farm coverage is negligible. They are to go a long way to make an impact in risk coverage as desired by the aquaculture farmers

due to many practical issues. However, insurance coverage is essential for small farmers and bankers are willing to finance the aquaculture sector in India.

Table. Insurance operation across the shrimp value chain

	Input system	Farmers	Markets	Processing	Exporters	Consumers
Items/Actors	1. Seed, 2. Feed 3. Other inputs, 4. Brooders & 5. Fish meal	1. Land 2. Ponds 3. Infrastructure 4. Labour 5. Credit	1. Aggregator; 2. wholesaler ; 3. Commission agents 4. Retailers 5. Vendors	HACCP Food Safety	1. Trade issues SPS/ 2. Non SPS rejections; 3. International relations; Exchange rate	1. Quality 2. Hygiene 3. Value for money
Insurables	1. Hatchery 2. Indigenous feed mills 3. Aerators/ motor/ Genset producers	1. Shrimp Nursery 2. Farm	1. Fish cold chain 2. Marketing infrastructure (yards, vehicles)	1. HACCP for hygiene 2. Antibiotics free products 3. Anti dumping		
Govt. Support & Insurance	1. Fire/ factory Insurance & other Nat cat cover 2. Fisherman Insurance (with State subsidy)	1.Flood/Fire/Motor /Bund insurance - rarely taken 2. No Crop Insurance	1.Business insurance 2. Govt. support	1. Freight insurance Merchandise Exports from India Scheme MEIS (Budger Rs. 2000 crores)- replaced w.e.f. 1.1.2021. Remission of Duties and Taxes on Exported Products (RoDTEP) - refund the embedded duties	1.Mediclaim 2. Health cover support from employers	

Vicious cycle of inefficient small farm aquaculture

Fig. depicts the vicious cycle of inefficiency of small shrimp farms due to absence of insurance and credit. As the farmers don't have adequate money, they go for poor seed and feed which results in poor performance of crop and further losses to the small scale shrimp farmer.

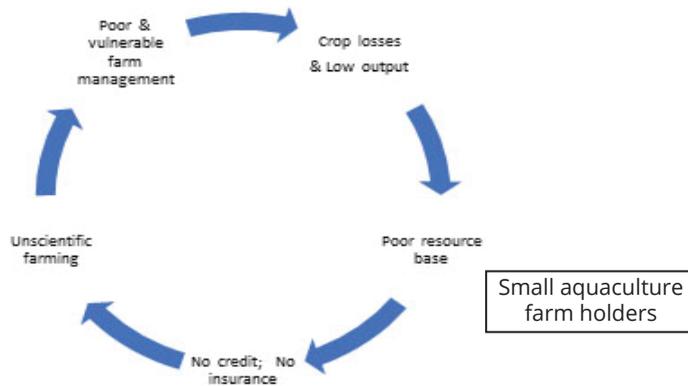


Fig. Vicious cycle of inefficient small farm aquaculture

Hot spots for insurance demand

Andhra Pradesh, Gujarat & TN produce 88% of farmed vannamei shrimp in India. Insurance market size for these states are estimated as

$$\frac{\text{Premium rate (Average input costs *Crop area (ha))}}{100}$$

100

The range of insurance market size estimate for 1% to 4% of total input costs are given in Table. An estimated market potential is Rs150 to 601 Crores per year for 1% to 4% of total input costs (20 to 40 Million USD)

Table. Market size of vannamei shrimp crop insurance premium

Farming area (ha)		1,00,206
Average Input costs (Rs)		15,00,000
Total turn over (Rs)		1,50,30,90,00,000
Premium rate (% to input cost)	1%	150,30,90,000
	2%	300,61,80,000
	3%	450,92,70,000
	4%	601,23,60,000

Based on the shrimp production data in 2020-21 (MPEDA, 2022), it is estimated Rs 750 crores per year as the business potential of shrimp crop insurance premium. Micro credit requirement is also estimated over Rs. 13,000 crores per annum, which is now being serviced by informal creditors at higher interest rates. A paradoxical situation exists with loss of profitable business to banks and insurance companies on one side, hardships of farmers with minimal access to credit and insurance on the other side. Bringing back access to insurance and institutional credit will help the in Doubling Farmers' Income in much faster time frame.

Table. Estimate of insurance premium and micro credit market of shrimp farming in India

S. No	State	Area ha (A)	Production MT (P)	Productivity kg/ha (Y)	Cost of production per ha @230 / kg vannamei	Value of Premium market segment @2% Rs. Crores	Value of Premium value market segment @4 Rs. Crores	State requirement of micro credit @ 70% scale of finance on input cost Rs. Crores
Vannamei shrimp ; Cost of production Rs. 230/kg								
1	Andhra Pradesh	71921	634672	8.82	2029651	291.95	583.90	10,218.22
2	Tamil Nadu	8600	44735	5.20	1196401	20.58	41.16	720.23
3	Gujarat	8986	50410	5.61	1290263	23.19	46.38	811.60
4	Others	8600	44735	5.20	1196401	20.58	41.16	720.23
5	Total	108526	815745	7.52	1728815	375.24	750.49	13,133.49
Tiger shrimp; Cost of production Rs.250/kg								
1	West Bengal	50000	19190	0.38	95950	9.60	19.19	335.83
2	Kerala	2813.85	1128.98	0.40	100306	0.56	1.13	19.76
3	Andhra Pradesh	2591	5222	2.02	503860	2.61	5.22	91.39
4	Karnataka	2175	1000	0.46	114943	0.50	1.00	17.50
5	Others	616.15	1075.02	1.74	436184	0.54	1.08	18.81
	Total	58196	27616	0.47	118634	13.81	27.62	483.28

Base data : MPEDA,2022. www.mpeda.gov.in

Problems faced by aquafarmers as insured policy holders

There are several constraints, as detailed below both to farmers and insurance companies in taking up and providing insurance schemes for aquaculture in India. The farmers in general are of the view that the government should provide insurance cover free of cost as they are contributing to the national income in a significant manner. The main points enumerated by farmers are:

- ❖ Expensive premium rates (6-10%) demanded by insurance companies.
- ❖ The unilateral discontinuance of insurance cover after a crop failure by the insurance companies as happened after the golden period of growth (1990-1994).
- ❖ The cumbersome documentation and 'small print' of terms and conditions and a massive list of exclusions "named perils".

- ❖ Practical difficulties of notifying insurance companies on emergency harvest situations.

General concerns of Insurers

Insurance companies are still unable to come out of barrage of indemnity claims received by shrimp farmers during 1995-97, which led to exit of insurance companies from shrimp crop insurance segment. The other technical issues faced by them are given below.

1. Scarcity of fisheries professionals in insurance companies and poor understanding of modern aquaculture systems and practices by generalists.
2. Worries about falsified claims.
3. Fear of huge losses in an epidemic/ new disease attack.
4. Workforce requirement and expenses burden of premium collection from a large number of farmers across the country.

Important target risks/perils in Indian shrimp farming-Farmer's interest

ICAR-CIBA has been conducting several farmers interactions and focus group discussions with shrimp farmers on risk under different project activities for the last 20 years. The essence of farmers interest on shrimp farming risks are as follows:

Risks and score in the rank of 1-10

1. Risks Production

1. Viral diseases (9) -Complete loss
2. Parasitic infection like EHP/ Running Mortality Syndrom (RMS)-(9) Partial loss
3. Price (8)
4. Policy (6)

2. Uncertainties

1. Adverse weather (7)
2. Floods, cyclones other Natural calamities(7)
3. Geo political conditions (6)
4. Pandemic (4)

Progressive costs and returns of shrimp farming

The progressive costs and returns, increase from day one and the breakeven occur between cumulative progressive costs & return and salvage (saleable value) is attained at 60 days of culture on an average. Hence farmers' loose entire amount if crop fails due to viral disease earlier than 60 DOC. After 60 DOC farmer gets some

salvage value to offset the loss at least to the extent of costs spent on inputs till date. (Fig.)

Farmers perspective on shrimp crop insurance (Fig.)

- ❖ Coverage for lesser period (40 to 75 days Max);
- ❖ Full cover
- ❖ Full claim
- ❖ At least 50% government subsidy from Govt

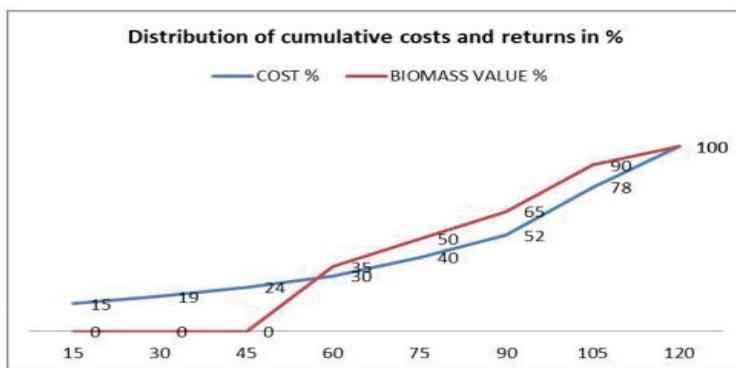


Fig. Progressive costs and returns of shrimp farming

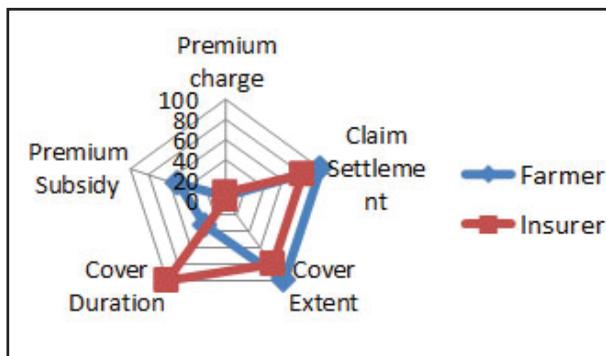


Fig. Radar chart visualizes mismatch between farmers and insurer’s interest

Main contradicting points between farmers and insurers on shrimp crop insurance :

- ❖ Cover duration (45 to 60 days Vs Full crop)
- ❖ Premium rate (more than 2%).
- ❖ Indemnity - 80% vs 100% of input cost

Capital formation in shrimp crop insurance is more than Rs.15,000 lakh crores in ponds, aerators, generators and other items. Shrimp aquaculture needs minimum of Rs.10,000 to 25,000 crores credit per annum. Internal Rate of Return is very high (more than 65%) in aquaculture projects. Recovery in shrimp loan is easy in compared to other sector loans. ICAR-CIBA suggested a credit of Rs. 3-5 lakh soft loan per ha can be given with collateral free /collateral standing crop/ Joint Liability Group for Small farmers

Product gap analysis of shrimp crop insurance

For a better and robust insurance scheme, there is a need to mitigate the fears and difficulties of both the insurers and insured. A product gap analysis of offers of insurers and demand of farmers is given in the following Table.

Table. Product gap analysis

Parameter	Current State-Insurance companies' offer	Desired State-Shrimp farmers requirement	Gap	Remedies suggested
Premium on sum insured (input cost)	2.7 to 4 %	1-2 %	1.7 to 2 %	Farmers awareness of insurance need to be increased; Government support, if materializes for 50% premium, will fill the gap
Coverage	80% of input cost	100% of input cost	20%	Government support on premium may offset this gap
Type of insurance	Parametric-weather based	Comprehensive including Disease cover	Unless disease loss is covered farmers not interested	Insurance companies need to engage qualified surveyors for aquaculture insurance

Type of loss	Total loss	Partial losses also to be covered	20 to 80%	Unless insurance companies have full-fledged aqua field staff, partial losses cannot be covered due to few delinquent/negligent claim cases
Duration	Full crop	45 to 60 days	40 to 60 days	Insurance companies should be made aware of insurance requirement from farmers' point of view

Source: Stakeholder meeting held at ICAR CIBA in August 2021 and March 2022.

The discussions with farmers' elucidated their willingness to take up shrimp crop insurance. But farmers' are expecting support from government on premium subsidy. The other expectations of farmers are full coverage, comprehensive insurance including disease cover for about two month period. The analysis of this desired state with current state of offer brings out the necessity of government support at least during kick start period. Government agencies need to conduct nationwide awareness campaigns to insurers and farmers to make the gaps to be bridged. The government can support the aquaculture crop insurance in the following ways:

1. Providing insurance as a central sector scheme by engaging state fisheries departments.
2. Providing 50% or more subsidy on insurance premium paid by the farmers as Direct Benefit Transfer.
3. Providing reinsurance to insurance firms at a reasonable and subsidized cost.
4. Ensuring sustenance of insurance scheme with an insurance stabilization fund as being done by some developed countries for different enterprises.

The first option however, is not workable on many counts, due to inherent issues in various state fishery department administrative setups. The second option can be considered by the NFDB. This scheme allows insurance companies to make and break their fortunes in light and dark periods of aquaculture. While increased

business profits may be lucrative in the short term, insurers may feel bitter when the size of the total claims may be large in the event of large-scale disease occurrence. Though reinsurance schemes are available to the insurance firms from the global level players, special terms and conditions are needed for aquaculture insurance. Government of India can establish an “Insurance stabilization fund” with a corpus of Rs 100 crores (or more) to be operated by a consortium of stakeholders’ viz., representatives of insurers, and insured along with official side nominees under the control of the ministry. Though only an area of 1.5 lakh ha is officially reported under *P. vannamei* farming, expert estimates of area under culture is almost double, if freshwater vannamei farming is also included. But only a fraction of these farms could get the license from CAA due to real-world issues. Hence an insurance coverage scheme may be run on a pilot scale in few clusters of registered farms with the involvement of a couple of willing insurance companies. Insurance companies can be allowed to reinsure with reinsurers if required on their own.

When a farmer harvests a good crop and there are only few claims, the insurance company will transfer the surplus to the insurance stabilization fund after deducting their administrative expenses and claims paid, if any. When large scale claims are received due to disease occurrence or any other reason, the insurance stabilization fund will compensate the loss to the extent as agreed upon. Insurance companies will have the freedom to reinsure with insurers as per their choice, which will be out of this scheme to protect their financial interests. As farmers essentially need insurance only for 60 days of the crop, the scheme can be operational for specific culture duration. After 60 days, farmers can breakeven most of the expenses with the harvest of the standing crop and its sale.

Credit in the aquaculture sector

Aquaculture provides huge business opportunities for banks as well. The capital required for shrimp aquaculture is estimated to be more than Rs. 7.5 to Rs. 10 lakhs per ha of farming in India and capital formation is Rs. 15,000 lakh crores for the Indian Aquaculture sector on the whole on assets such as ponds, aerators, generators, and other valuable items. Apart from this, modern aquaculture segment also requires a minimum of Rs.10, 000 to 15,000 crores credit for each crop period, and the role of credit is vital for the sustenance of the sector. As the supply chain is fully interconnected and transparent in the shrimp value chain, the loan recovery process is easy for credit institutions, when compared to many agricultural, industrial, and other sectors. The Indian government could ease the credit policy and ask the formal credit sector to sanction collateral-free loans or credit with lower collateral for aquaculture with an increase in productivity. The importance of credit and insurance support required for farmers cannot be undermined, irrespective of technological

advancements and commercial viability of shrimp farming. Organizations such as the National Fisheries Development Board (NFDB) should step up its efforts to streamline aquaculture crop insurance to farmers, as already sufficient efforts have been put up in this regard. The National Bank for Agriculture and Rural Development (NABARD) should devise methods of access to credit without collateral. Joint Liability Group (JLG) should be promoted in the aquaculture sector also and other systems of collective protection may be designed to safeguard farmers as well as banks. These efforts will ease the problems of small and marginal shrimp farmers who are the backbone of the sector.

Conclusion

Despite bio-security and all precautions, curable and incurable diseases do occur in ponds lead to losses to the farmers. Insurance can help small farmers to tide over such crop losses. The risk to insurance companies is limited as the crop is only for duration of 100 to 110 days and after 60 days, salvage value will help to reclaim breakeven costs to the farmers and reduce the liability to the insurers. The pilot scheme can be extended by phases, including more farmers, other aqua-crops, large number of insurance firms, and increasing corpus of Insurance stabilization funds.

ICAR-CIBA MOBILE APPLICATIONS FOR AN EFFICIENT SHRIMP FARM MANAGEMENT

M.Kumaran, D.Deboral Vimala and S.Jayapavithran

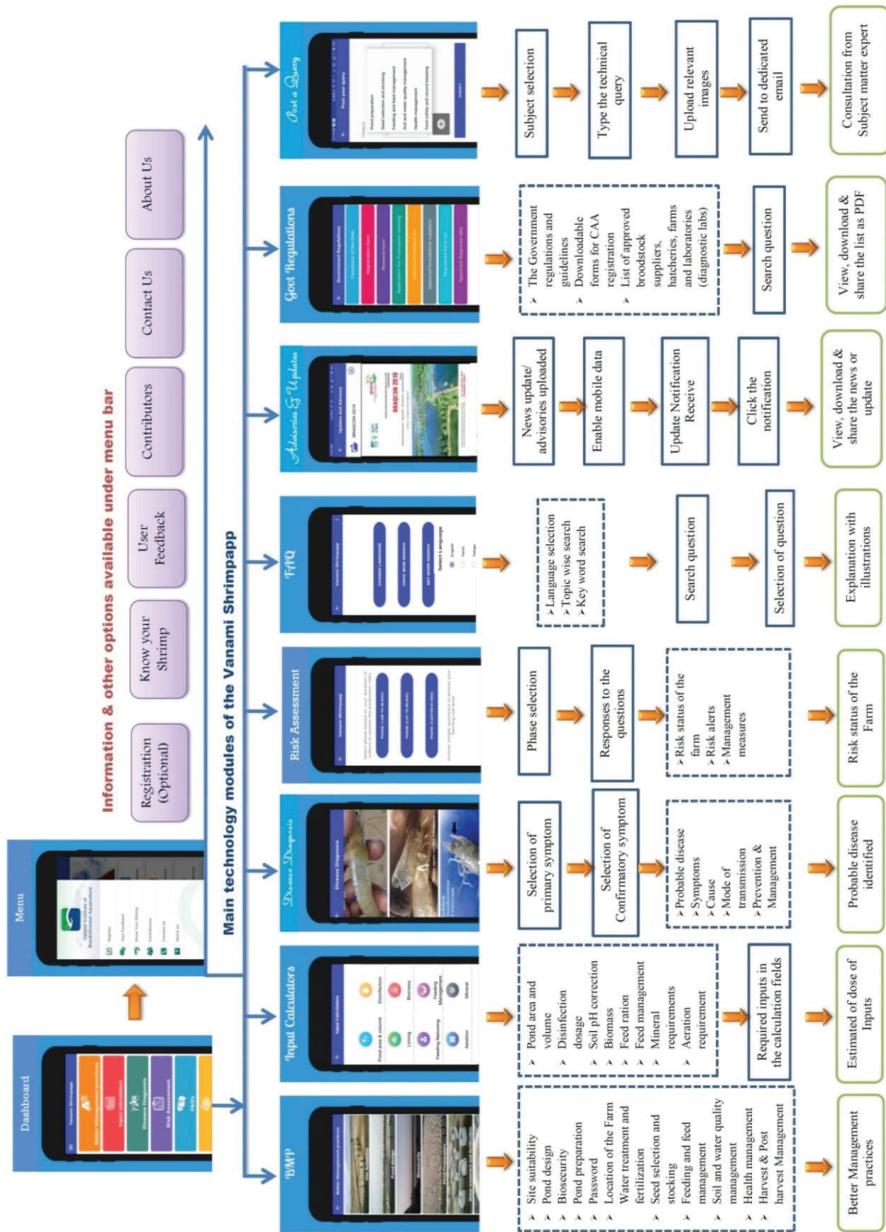
Introduction

Shrimp farming, the growing of shrimps in manmade ponds under controlled conditions is mostly practiced in the coastal areas adopting diverse production systems at different scales by dissimilar strata of farmers. It is technology driven, capital intensive and coupled with many production oriented risk like diseases, increasing production costs and narrow profit margins. The farmers need to adopt innovative strategies to prevent the risks, and increase the productivity and profitability. Shrimp farms are located in remote areas and the farmers need customised farm advisories, which the conventional extension approaches are unable to provide. At this juncture, development of telecommunication networks that support greater data speeds and connectivity even in remote geographies and affordable prices of mobile handsets paved the way for developing mobile applications to bridge this communication gap. It is highly proven that mobile applications are found to have ensured bidirectional information flow, provide customised advisories to the farmers, broke information asymmetry and enhanced knowledge level of farmer segments. The shrimp farmers are qualified, techno-savvy, afford to have smart phones and voracious information seekers from diverse sources. Therefore, mobile applications on shrimp farming can facilitate farmers in updating their skill sets and efficient management of farming operations using the real-time data. Mobile application facilitated shrimp farm management refers to facilitating shrimp farmers with customised technology advisories, input optimizing calculations, bio-mass/stock assessment, on-farm disease diagnosis, pond-wise digital record keeping, easy monitoring of pond parameters and offer recommendations based on the data fed in to it. In this line, ICAR-CIBA developed two android mobile applications - CIBA ShrimpApp and CIBA ShrimpKrishi- to enhance the skill sets of end-users and facilitate the farmers in managing their farms efficiently. The apps are available in the Google play store for free of cost.

Modules of the mobile application

The framework and modules of CIBA ShrimpApp is given in the Fig. and a brief description of the modules is given below.

- i. *Module on Better Management Practices (BMPs)*: It contains textual as well as pictorial contents on shrimp farm site selection, pond design, pond preparation, seed selection, stocking, feeding, feed management, soil and water quality management, health management, farming regulations, food safety and record keeping which are lucidly explained with illustrations.
- ii. *Input calculation module*: The module on inputs calculations contains eight calculators to estimate the critical inputs for shrimp farming, viz., the pond area and volume, total biomass in the pond, disinfection requirements, feed rationing, feed management, mineral requirement, soil pH adjustment and aeration requirement. The end user has to enter the relevant input parameters after which the results would be displayed with the respective units.
- iii. *On-farm disease diagnosis module*: An image-based disease diagnosis module has been incorporated. The user can identify a disease infection on farmed shrimp probabilistically by comparing the symptoms of farmed shrimp with a given list of images of diseased shrimp. It contains two sets: common and confirmatory symptoms of known diseases. The end-user has to choose the relevant images in both the categories and if the symptoms are matching in both the sets, the application would display a probable disease (needs confirmation with lab tests) and display further information on causes, management etc., which will enable the end-user to make an informed decision. In case the symptoms do not match in both the sets, then the app would advise the user to upload the symptoms and other parameters as a query in the post-a- query option of the app.
- iv. *On-farm risk assessment module*: The user can assess the production risk status of his/her shrimp farm by answering a sequence of Multiple Choice Questions (MCQs). The module is further divided into three phases (Phase-1- up to 40 days of culture; Phase-2- between 41-80 days of culture and Phase-3- above 81 days of culture) and the user depending on his crop stage, can choose the required phase. In each category, a set of MCQs are placed. Whenever, the user chooses a wrong answer for critical questions, a pop-up menu automatically appears and displays that his farm is at risk. The user can continue answering and at the end, the module displays the risk level of the farm, risk factors and recommends appropriate management measures to tackle those risk factors.



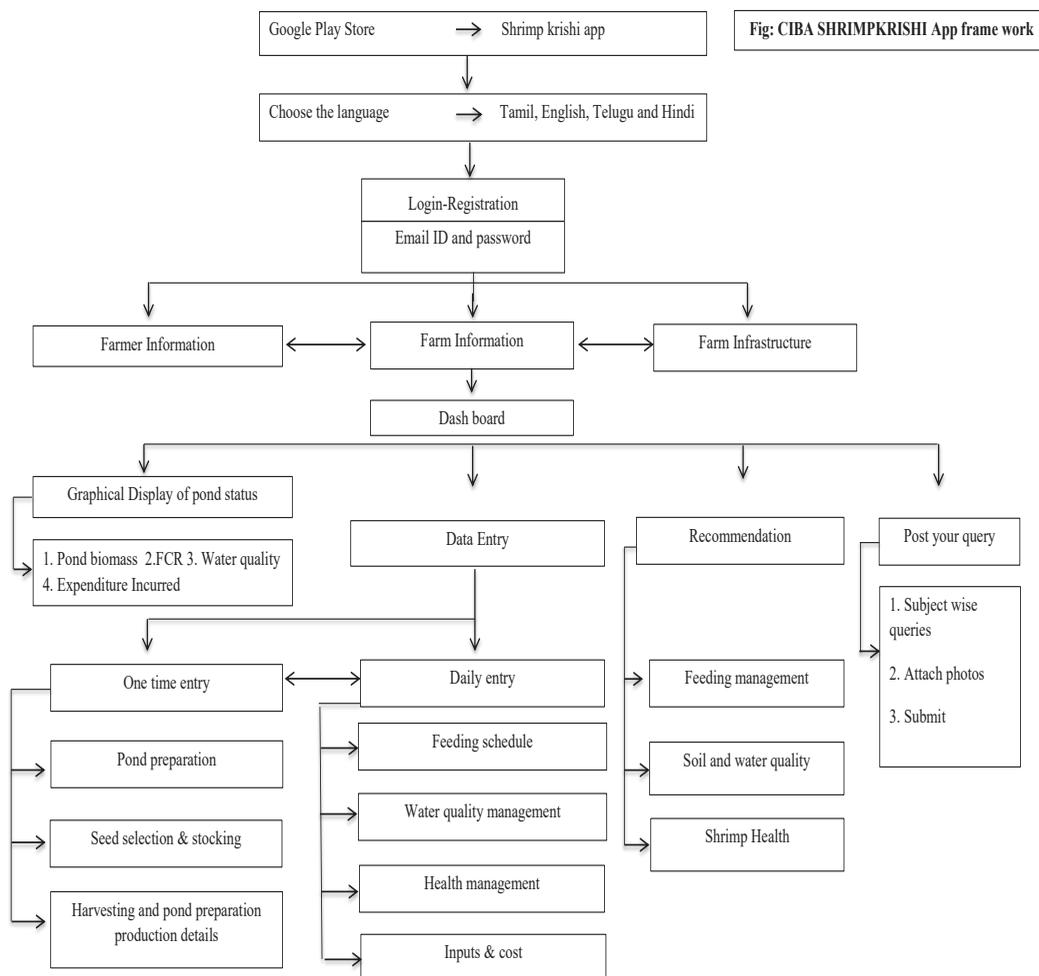
- v. *Updates and advisories module:* A dynamic module on updates and advisories enables the user to receive real time advisories and updates posted by the host institution. The updates are in the form of downloadable PDF files. The users receive notification when files are uploaded and can later be downloaded when the user connects with the mobile data.
- vi. *Government of India regulations and guidelines module:* The regulations and guidelines for shrimp farming stipulated by the Government of India were summarized in a module along with downloadable utility forms for registration/renewal of farms with the Coastal Aquaculture Authority (CAA) of India, the regulatory body of the Government. In addition, it contains the lists of approved brood stock suppliers, hatcheries (seed sources), farms and laboratories (diagnostic labs) as posted in the CAA website. This compact information is extremely useful for the stakeholders. This compact information is extremely useful for the stakeholders.
- vii. *FAQ module:* The FAQ module contains possible queries along with explanations related to *P. vannamei* shrimp farming from pond preparation to post-harvest handling. The user can choose the language (vernacular) and font size to make it easier to read and comprehend. Keyword based search option is also available to list the queries on a particular topic.
- viii. *Post-a-query module:* The important feature is the “Post a query” module, through which the end user can submit the query in the form of text or/and images of his shrimp or pond which is received as an e-mail message in the dedicated mailbox at the host institute. The expert advisory on the queries are responded to within two working days (48 hours).



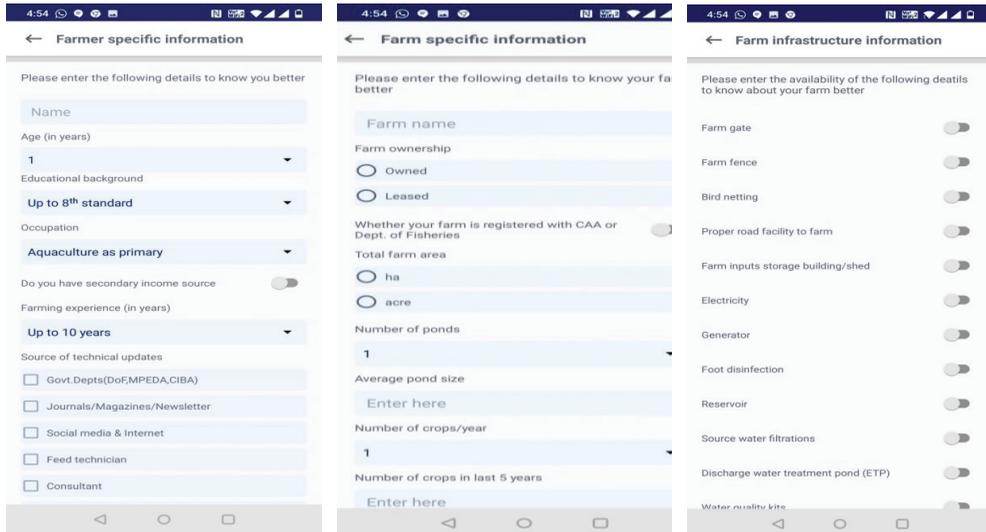
Fig. Mobile app based disease diagnosis module on *P.vannamei* shrimp farming

The Modules of CIBA ShrimpKrishiApp

The framework and modules of CIBA ShrimpKrishiApp is given in the Fig. and a brief description of the modules is given below.



The CIBA ShrimpKrishi is an action oriented application works purely based on the data provided by the end-user and it is available in four languages viz., English, Hindi, Tamil and Telugu. The end user has to log-in and complete the registration by providing required basic data about the user, his farm profile and infrastructure available. Upon completing the registration the dash board of the app appears.



The dashboard contains four buttons viz., one-time entry, daily entry, recommendations and post a query buttons. The user has to do the data entry pond wise under each item.

Data entry: The data entry in the mobile application is of two kinds Viz., farm information and pond wise information (fig-1). Farm information is comprised of basic profile of the farmer and farm details. Farm information is one- time data recording, whereas, pond wise data entry is of three kinds:

- ❖ **Pond wise entry - once in a crop:** Pond preparation protocols, seed selection and seed stocking details (stocking density, seed size), harvesting and production.
- ❖ **Pond wise entry - whenever the data available:** Water quality parameters, input applications etc. as and whenever they are tested and inputs applied.
- ❖ **Pond wise entry - mandatory daily entry:** Water quality parameters, feed rationing and management protocols, animal health monitoring protocols and the cost associated with

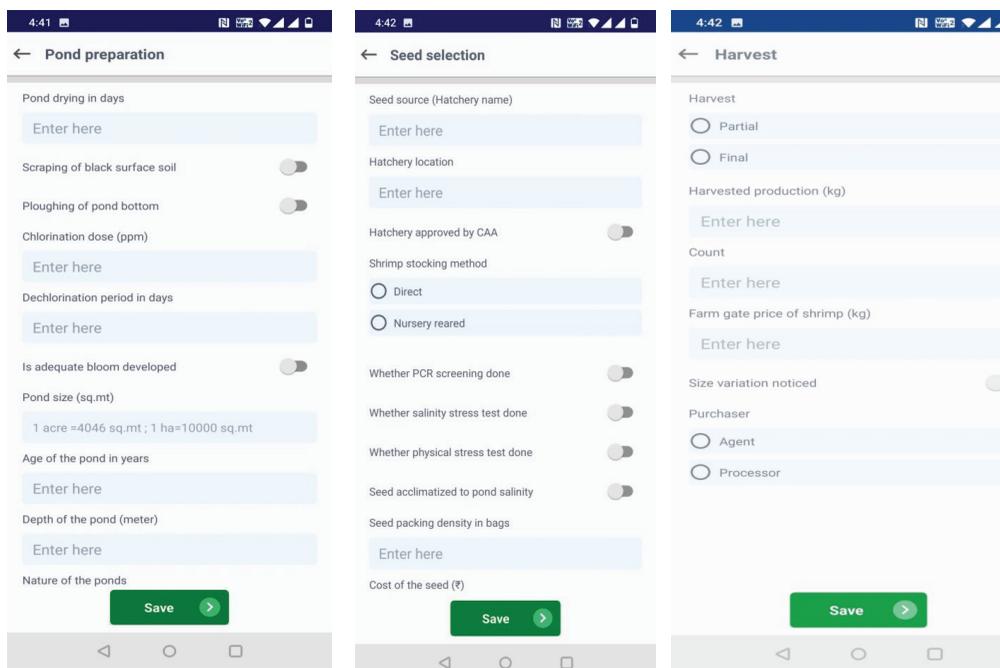
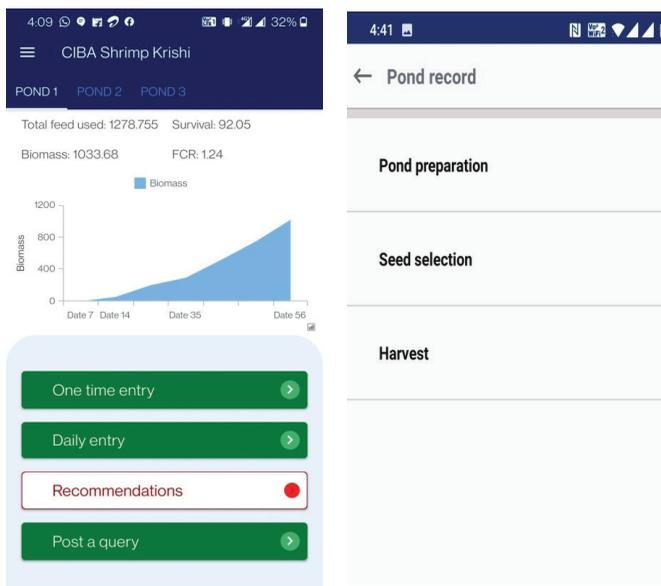


Fig. Pond wise Entry – once in a crop

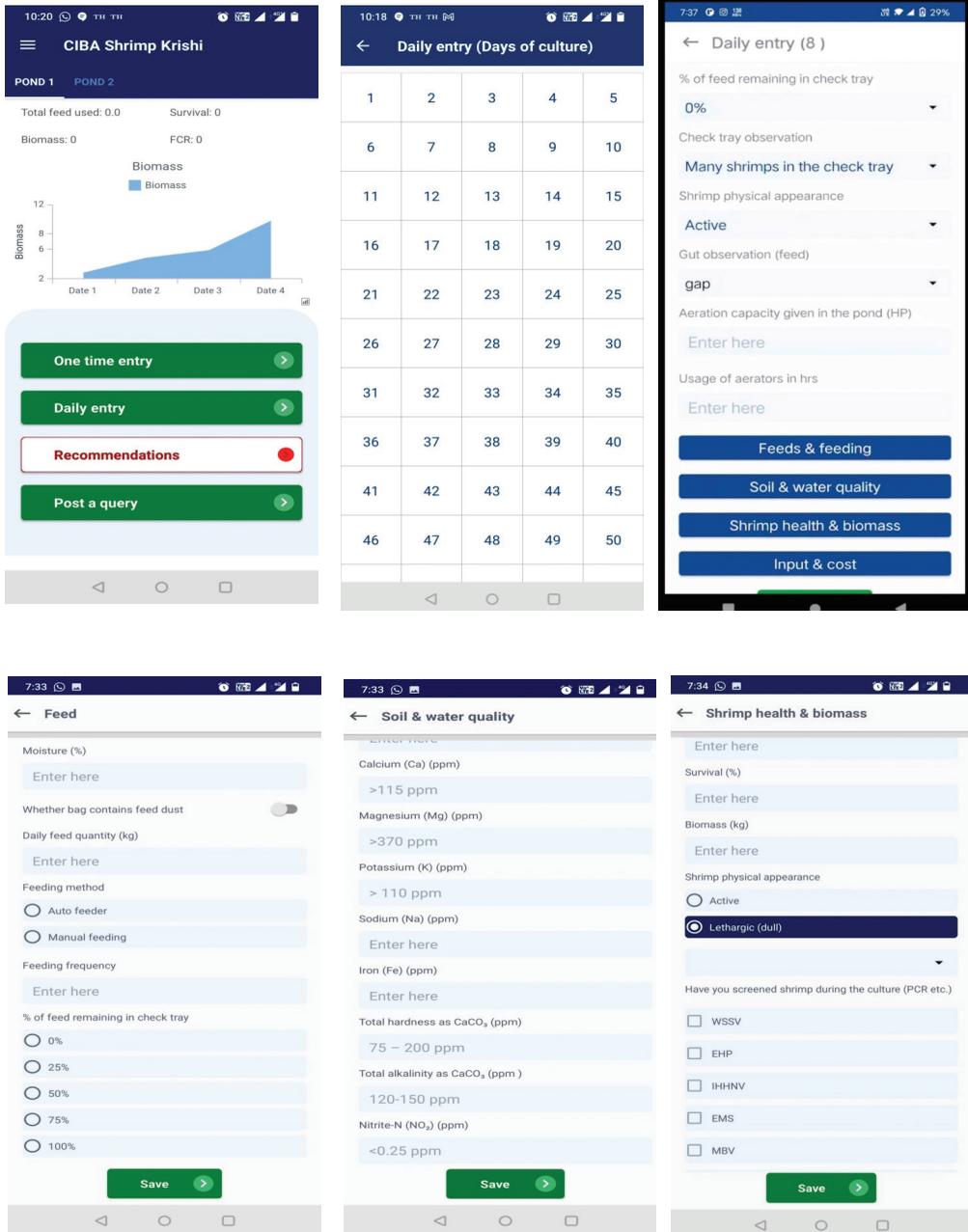
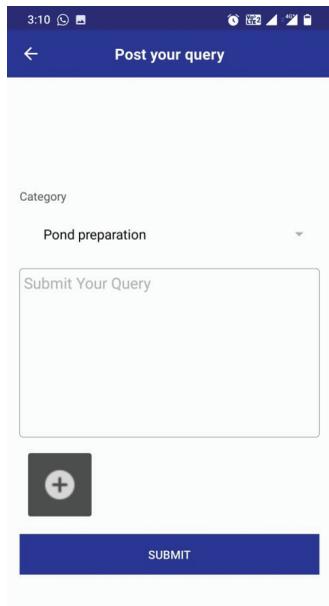
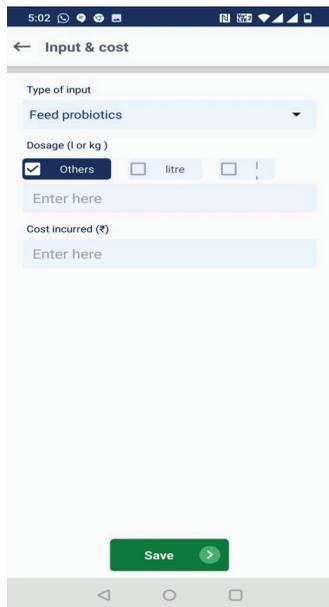


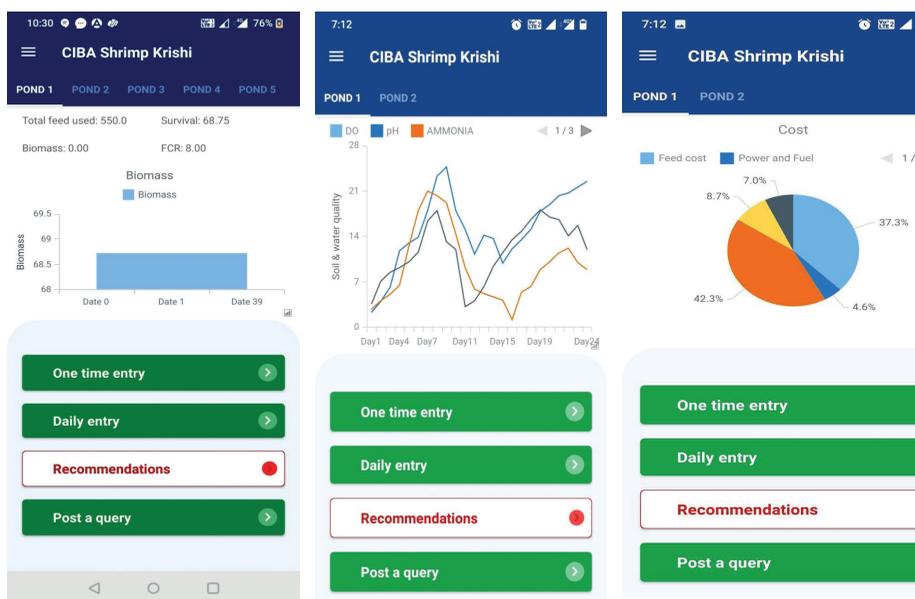
Fig. Pond wise Entry - on regular basis



Whenever the farmer is entering the data he/she has to click the SAVE button in each menu then only the data are saved and added in to the existing data on that

parameter. From first day of culture (DoC-1) the end user has to enter his farming operations data pond wise as indicated so that the app will display the results by pond wise for monitoring. Once the data are build up day by day the dash board would start displaying graphs on the survival, FCR and biomass, water quality parameters and cost incurred on various aspects in every pond on a finger stroke. Three expert systems viz., shrimp feed management, water quality management and shrimp disease management are inbuilt in to the app. Based on the data fed in to the app, it alerts the end-user farmer with technical advisories whenever any deviations are noted in the pond operations and critical day-to-day parameters such as water quality, feeding and shrimp health.

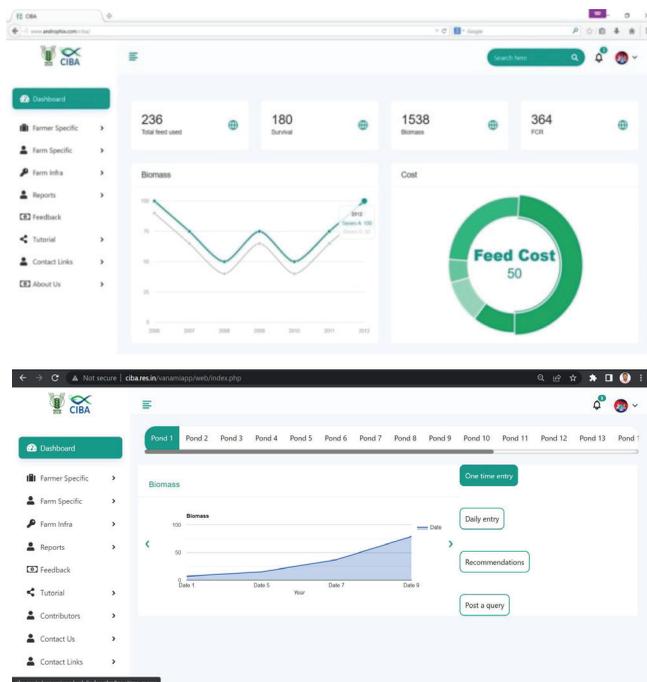
Fig. Graphical recommendations of shrimp pond parameters in the App



The app can store the entire crop data in it pond wise and the farmer can check the data on any of the day of culture by choosing the DoC in the data entry menu. The end user can retrieve the data for their own long-term decision-making purposes or share it with their resource person for technical advice. Moreover, it paves the way for accessing real-time bulk data from the remotely located shrimp farms to monitor and extend customized technical advisories.

Conversion of ShrimpKrishiApp in Windows platform: The app is converted in to windows platform as per the feedback given by the end-user shrimp farmers. The

end-user can enter the data using their lap-top for ease of entry. Both the Android and Windows platforms are synchronized so that the data entered and saved in one mode can be seen in the other mode and vice versa. Saving the data on each time in each item is crucial for accurate display of results.



Conclusion

The farmers and extension workers perceived that CIBA mobile applications are the potential tools for knowledge improvement and efficient farm management. It enabled the bidirectional flow of information between the research institution and end users in getting field feedback through receiving and answering queries. Considering the all-pervading mobile application based technology advisories play a major role in minimizing the information communication gap in shrimp aquaculture and it may help to a large extent to speed up and enhance the quality of the farm extension services. The shrimp farmers should make use of these applications and give feedback for improving the applications. The ShrimpKrishi is an important application wherein the farmer store and retrieve pond wise information would help the farmers in making informed decisions. Further, the days are very nearer to make this app mandatory by development agencies to avail institutional incentives. .



“ReportFishDisease”

A Mobile Application for
Aquatic Animal Disease Reporting



Developed under

National Surveillance Programme for Aquatic Animal Diseases

Funded under

Pradhan Mantri Matsya Sampada Yojana
Department of Fisheries, Ministry of Fisheries, Animal Husbandry and Dairying
Government of India

Coordinated by

ICAR-National Bureau of Fish Genetic Resources Lucknow, India

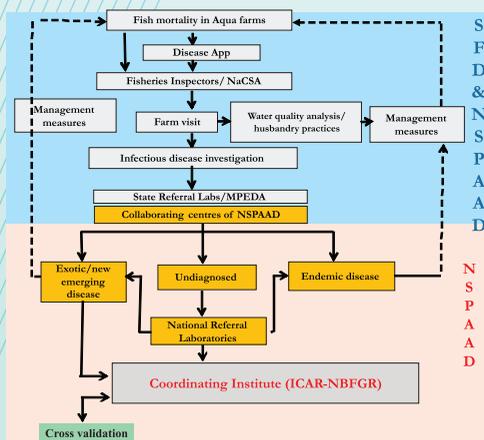




Rationale for Developing an Aquatic Animal Disease Reporting Mechanism

- ☞ Aquaculture sector is witnessing an impressive growth over the years
- ☞ However, the diseases are the most significant constraint to the growth of the aquaculture
- ☞ Early detection of diseases is important for eradication or containment of exotic or emerging diseases and management of endemic diseases
- ☞ Often in aquaculture go unreported due to unavailability of the field-level disease reporting mechanism
- ☞ Therefore, there is a necessity of a mechanism that can connect farmers, field-level officers and fish health experts for strengthening the farmer-based disease reporting
- ☞ Keeping the same in consideration, for improving the reporting of aquatic animal diseases in the country, a 'ReportFishDisease (RFD)' App has been developed by ICAR-National Bureau of Fish Genetic Resources (NBFGR), Lucknow

Proposed Mechanism of Disease Governance



ReportFishDisease App



Usefulness of the App

- ☞ Using the RFD app, the farmers can report incidence of disease in finfish, shrimps and molluscs on their farms with the field level-officers and fish disease experts and get scientific advice.
- ☞ The data regarding the diseases will be stored on temporal and spatial scale and can be used for mapping the disease cases.



Features of ReportFishDisease App

- 📱 Android-based mobile app available on Google Play store
- 📱 Sign in using OTP
- 📱 Automatic ge-tagging of the pond, hence data needs to be filled at pond site
- 📱 The app is currently available in English and Hindi, and will be available soon in regional languages
- 📱 User friendly interface – most of the details to be filled are given as check boxes
- 📱 The download size of the app is small
- 📱 Data protection is encrypted in the app
- 📱 Separate forms for reporting cases of diseases affecting Finfish, Shrimp and Mollusc
- 📱 Information about important diseases is provided in the App
- 📱 Different levels of 'Admin' for efficient functioning
- 📱 Provides a link to important National/International Organizations in fisheries sector

Panels of ReportFishDisease App



Farmer Dashboard



Reporting a Disease Case



Disease Reporting Forms

Finfish



Shrimp



Mollusc





Tracking a Submitted case and Response Mechanism in the App



Following submission of disease report by the farmer, the same would go to the respective State Fisheries Department and NSPAAD Collaborating Centre who would investigate the case and suggest management measures. The Coordinating Institute would monitor all the disease cases reported by the farmers.

Admin Dashboards



Epilogue

It is expected that the App would help in improving farmer-based reporting, getting scientific advice and reducing losses due to diseases, thereby increasing farmers' income.

ROLE OF NATIONAL FISHERIES DEVELOPMENT BOARD IN FISHERIES DEVELOPMENT IN INDIA

Bijay Kumar Behera

The National Fisheries Development Board (NFDB) established in 2006, is an autonomous organization under the administrative control of the Department of Fisheries (DoF), Ministry of Fisheries, Animal Husbandry and Dairying (MoFAHD), Government of India (GoI), Headquartered in Hyderabad, NFDB has 3 regional centres; NFDB-Eastern Regional Centre (NFDB-ERC) at Bhubaneswar, Odisha and NFDB North Eastern Regional Centre (NFDB-NERC) at Guwahati, Assam and Centre of Excellence in Mariculture, Andhra Pradesh. NFDB aims to enhance fish production and productivity in the country and coordinate its fishery development activities in an integrated and holistic manner.

Activities of NFDB

A wide range of fisheries and aquaculture development activities are carried out by NFDB which can be summarised as below:

Livelihood and entrepreneurship

NFDB plays a pivotal role in improving the livelihoods of over 2.8 crore fisheries and aquaculture stakeholders across India. The Board is implementing two insurance schemes in the sector i.e. Group Accident Insurance Scheme (GAIS) under the Pradhan Mantri Matsya Sampada Yojana (PMMSY) to provide financial and livelihood security to fishers in case of accidents, disability & hospitalization and Aquaculture Insurance under Pradhan Mantri Matsya Kisan Sah Samridhi Yojana (PM-MKSSY) to fish farmers for crop loss due to un-preventable risks.

NFDB is also being entrusted with supporting the formation of 6,000 new fishery cooperative societies and strengthening around 5,500 existing fishery cooperatives through existing GOI schemes including PMMSY, PM-MKSSY, Fisheries and Aquaculture Development Fund (FIDF) etc. This would provide small and marginal farmers, including marginal fishermen engaged in fish production, with requisite forward and backward linkages, skill development, processing and cold chain infrastructure facilities, thus enabling them to increase their incomes. NFDB provides ₹ 3 lakh as a one-time grant to each newly formed Fisheries Cooperative Society (FCS) to enable them with initiating the business activity. The newly formed FCS are to undergo training, prepare viable business plan upon which the financial

assistance will be released through the state fisheries department for better implementation at field level.

Apart from these, NFDB implements need-based, beneficiary-centric development initiatives under the framework of 'Entrepreneur Models'. Under PMMSY, a minimum allocation of ₹ 100 crore is earmarked for 'Entrepreneur Models'. The completed projects under this component include the establishment of pre-processing units, advanced processing facilities such as Individual Quick Freezing (IQF) units, cold storage infrastructures, fish value addition and drying units, as well as fish markets and trade centres. Additionally, the development of cold chain logistics is also supported through the deployment of refrigerated and insulated vehicles.

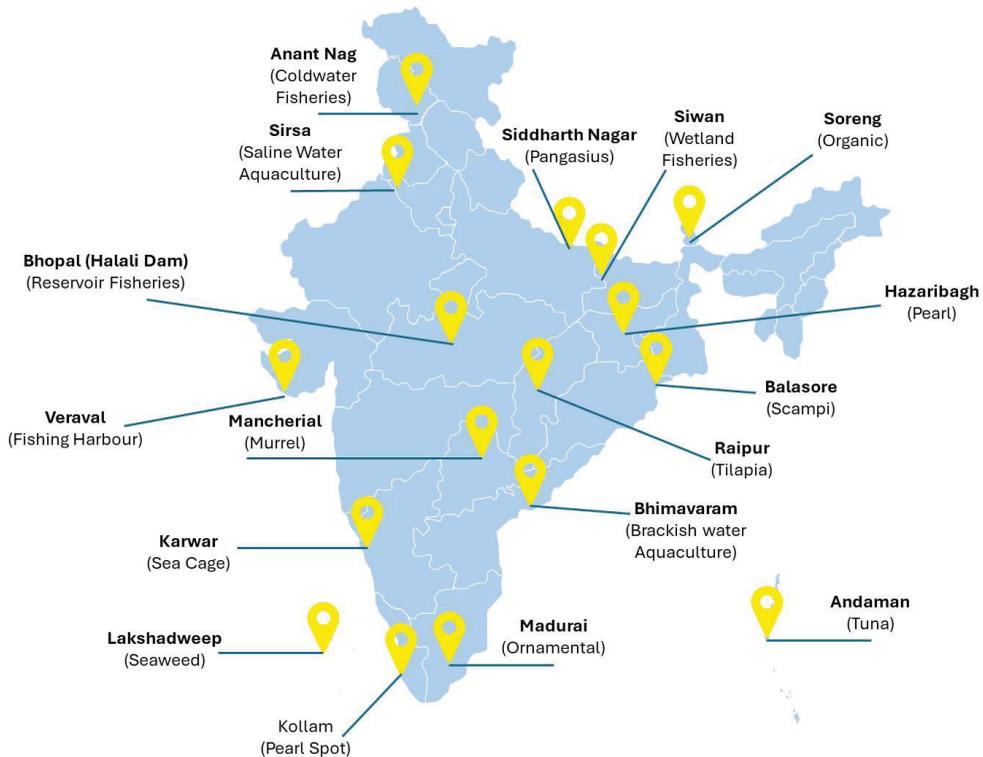
Infrastructure development

To facilitate modern harvest and post-harvest technologies, NFDB supports introduction of deep-sea fishing vessels and the development of shore-based infrastructure such as fishing harbours, fish landing centres, ice plants, etc. Apart from these, construction of cold storages, fish transport facilities, integrated cold chain, fish processing units, modern fish markets, etc. are being supported financially by NFDB to improve handling, processing, storage, and marketing of fish. The Board extends its financial assistance towards infrastructure development in aquaculture too, such as setting up of brood banks, hatcheries, fish feed mills /plants, disease diagnostic laboratories & aquatic quarantine facilities, establishment of cage culture in reservoir, rivers, coastal waters & open sea, modernization of fish seed farms, etc. NFDB facilitates the establishment of state-of-the-art fisheries training centres to promote knowledge sharing, innovation, and sustainable practices among the stakeholders. These infrastructure initiatives are part of the initiative of FIDF introduced by the GoI, facilitating low-interest loans for infrastructure projects, complementing the flagship scheme PMMSY.

Aquaculture promotion

NFDB encourages intensive aquaculture such as Recirculatory Aquaculture System (RAS) & Biofloc system for aquaculture, culture-based fisheries in reservoirs and wetlands, cage aquaculture to utilise vast waterbodies, shrimp culture in inland saline areas, cold-water aquaculture in raceways, diversification of aquaculture species etc. In coordination with the DoF, GoI, NFDB identifies and supports the development of geographically concentrated areas focused on specific fisheries and aquaculture activities. In continuation of this, the DoF, GoI has announced 17 such clusters across the country including Pearl Culture Cluster in Hazaribagh, Jharkhand, Ornamental Fisheries Cluster in Madurai, Tamil Nadu, Seaweed Cluster

in Lakshadweep, Tuna Cluster in Andaman & Nicobar, Organic Fisheries Cluster in Soreng District, Sikkim etc.



Quality fish seed promotion

NFDB-ERC-National Freshwater Fish Brood Bank (NFFBB) is working to improve fish seed quality and production of Genetically Improved Fish Species (GIFS) through a network of registered hatcheries and seed growers. Under this Networking Project, accredited hatcheries will develop GIFS broodstock using breeder seed supplied by NFDB-ERC-NFFBB. These hatcheries will produce spawn, which will be distributed to seed growers. In turn, the seed growers will supply quality seed to fish farmers. To facilitate the development of quality breeder fish seed, NFDB collaborates with ICAR-Central Institute of Freshwater Aquaculture (ICAR-CIFA) for providing Genetically improved (GI) varieties of Rohu (Jayanti Rohu), Catla (Amrit Catla), and GI Scampi, Karnataka Veterinary Animal and Fisheries Sciences University (KVAFSU) for Amur Common Carp (a Hungarian Common Carp strain), ICAR Central Institute of Fisheries Education (ICAR-CIFE) for GI Desi Magur. These are later multiplied at NFDB-ERC-NFFBB.

Technology and innovation

The Board promotes modern fish farming techniques, such as the development and distribution of genetically improved fish seed, vertical crab culture, use of Phase Change Material (PCM) in post-harvest quality preservation of fish, Integrated Multi-Tropic Aquaculture (IMTA) as an alternate livelihood of fishers, scientific breeding practices, knowledge-based farming, use of drones in aquaculture input application across the waterbodies, etc. To feature presentations on drone technology and to highlight its potential benefits such as transportation of fresh fish, fish input dispensing, distribution of emergency aid like dispensing life jackets etc., NFDB in coordination with DoF, GoI has initiated outreach programs on drone technology demonstrations in various activities in fisheries and aquaculture sector nationwide. Till now outreach programs were organised at ICAR-CIFRI, Barrackpore, Gyan Bhawan, Patna, ICAR-CMFRI, Kochi, NFDB, Hyderabad etc.

Diversification and sustainability

NFDB works on species and process diversification and climate-resilient practices to adapt to changing environmental and market conditions. To promote species diversification, NFDB funds sea weed culture, bivalve culture, pearl culture, development of genetically improved varieties of existing fish species, breeding and aquaculture of indigenous fish species of North East Indian region etc. As part of process diversifications, the cage culture, RAS, biofloc systems, etc. are being promoted. Environmental sustainability and conservation are two significant components of NFDB's outlook.

To facilitate this, NFDB endorses establishment of artificial reefs & fish aggregation device, popularization fuel-efficient long-lasting otter boards etc. NFDB has already approved the development of 100 Climate-Resilient Coastal Fishing Villages (CRCFV) under the Annual Action Plan 2024-25, with a total outlay of ₹ 200 crore. This initiative aims to enhance the economic resilience of coastal communities impacted by climate change. This includes modernizing drying yards, processing centres, fish markets, etc. establishing emergency rescue services and promoting climate-resilient practices such as seaweed cultivation, artificial reefs, green fuel projects etc. With the objective of addressing the pressure on native fish stock in rivers, replenishing the indigenous species and in turn improving the livelihood of fishers, river ranching component has been incorporated under PMMSY. The scheme is being implemented by NFDB in the river basins viz. 1. Ganges and the tributaries of Ganges River system 2. Brahmaputra and Barak River tributaries and adjoining rivers 3. Mahanadi and tributaries of Mahanadi River system 4. Wainganga and Wardha Rivers 5. Cauvery River and adjoining rivers 6. Godavari, Narmada and

Indus River systems. So far, the fingerlings of Rohu, Catla, Mrigal, Brown trout and other locally available native species are being ranched. The programme aims to achieve sustainable fisheries management, conservation of biodiversity and better socioeconomic benefits. Likewise, sea ranching is being carried out by NFDB in coordination with the respective States Gujarat, Tamil Nadu, Andhra Pradesh and Kerala, with targeted species Cobia, Silver Pompano and Indian Pompano.

Training and capacity building

NFDB is the designated nodal agency for executing training, awareness, exposure, and capacity building activities including skill development/ upgradation programmes under PMMSY. The Board collaborates with and financially supports various entities like central & state government departments, ICAR & other research institutes and private agencies to implement training programs & exposure visits for fisheries stakeholders including, women, youth, backward communities etc., to conduct fish festivals to improve domestic consumption, and to organise conferences/ events to enable knowledge sharing.

Digital Initiatives

NFDB is implementing the Fish Market Price Information System (FMPIS), a 'smartphone- Android-based platform that collects and analyses fish price data from major markets to support informed decision-making, from 2019. NFDB also supports the flagship initiative of Gol the

National Fisheries Digital Platform (NFDP) developed under PM-MKSSY. The platform was launched recently by the DoF, Gol in coordination with NFDB, to formalise the Indian fisheries and aquaculture sector through creation of a database of work-based identities for all fisheries' stakeholders.

Policy Implementation

NFDB is a key implementing agency for government schemes like the PMMSY, its sub-scheme PM-MKSSY and FIDF by facilitating project appraisal, monitoring, & capacity building and aligning national policy with grassroots execution. The developmental activities of NFDB are being implemented under different initiatives of Gol, through the State & Union Territory Governments and other End Implementing Agencies (EIA). In essence, NFDB is the backbone of India's fisheries transformation — bridging traditional practices with modern science to ensure food security, economic growth, and environmental sustainability.

Opportunities for Scientific Community

PMMSY & its sub-scheme PM-MKSSY is a great platform for the scientific community (a) to establish/ carry out their research outcomes/ inventions in a larger scale and (b) to expand their basic research to applied research for bridging the existing gaps in the fisheries sector. The fully funded components like Genetic improvement programmes and Nucleus Breeding Centres (NBCs), Innovations and Innovative projects/activities, Technology demonstration including startups, incubators & pilot projects, Training, Awareness, Exposure & capacity Building, Aquatic Quarantine Facilities, Disease Monitoring and Surveillance Network etc. may be explored further by the community.

BLUE ECONOMY CATALYST: MPEDA'S ROLE IN POWERING INDIA'S SEAFOOD EXPORTS

D. V. Swamy

The Marine Products Export Development Authority (MPEDA) was set up by an act of Parliament during 1972. The erstwhile Marine Products Export Promotion Council established by the Government of India in September 1961 was converged into MPEDA on 24th August 1972. The Marine Products Export Development Authority under the Ministry of Commerce and Industry is a statutory body entrusted with the primary task of promotion of export of marine products.



The Authority consists of 30 members including a Chairman (Appointed by the Central Government), Director, 3 Members of Parliament of whom two shall be elected by the House of the People and one by the Council of States, 5 members representing Central Ministries of Agriculture, Finance, Foreign Trade, Industry, Shipping and Transport and 20 other members to represent the Maritime States and other relevant fields as specified in MPEDA Rules, 1972.

Functions of the authority

The MPEDA Act of 1972 assigns several key functions to the Authority, tasking it with promoting the development of the marine products industry under the control of the Central Government, with a special focus on exports. To achieve this, the Authority undertakes a range of measures including the development and regulation of off-shore and deep-sea fishing, as well as conservation and management of these fisheries. It is responsible for registering fishing vessels, processing plants, storage premises, and transport conveyances used for marine products. The Authority also fixes standards and specifications for marine products intended for export, ensuring quality control through inspections at various stages—from fishing vessels to storage facilities and transportation. Financial and other assistance are provided to owners

of fishing vessels and processing units, including acting as an agency for relief and subsidy schemes entrusted to it.

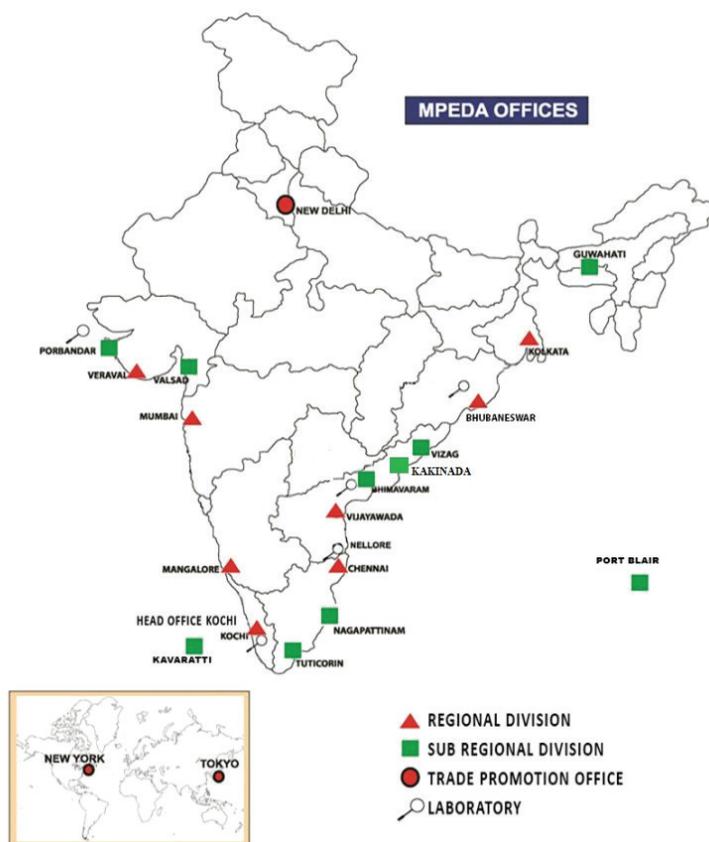
Moreover, the Authority regulates the export of marine products and works to improve their marketing internationally. It oversees the registration of marine product exporters and collects and publishes statistics related to the industry, covering all stakeholders involved in fishing, processing, transportation, and export. Training programs in various aspects of the marine products industry also fall under its mandate. All functions performed by the Authority are carried out in accordance with rules made by the Central Government, ensuring compliance with prescribed regulations. This comprehensive role enables MPEDA to act as a central body for promoting sustainable growth, quality assurance, and enhanced global competitiveness of India's marine products industry.

Committee of the authority

The Committee structure of the Authority is designed to facilitate its varied functions through specialized groups. The Executive Committee comprises the Chairman, Vice-Chairman, Director, Secretary, and three elected members from the Authority, overseeing overall governance and decision-making. The Technical Committee includes the Chairman, Vice-Chairman, Director, and eight additional members elected from among the Authority's members, focusing on technical and scientific aspects of the marine products industry. Meanwhile, the Export Promotion Committee consists of the Chairman, Vice-Chairman, Director, and three elected members, working specifically to advance export activities and opportunities.

Establishments of the authority

To effectively carry out its export promotion and aquaculture development functions, the Authority has established a widespread presence across all maritime states of India. It operates through eight Regional Divisions, ten Sub-Regional Divisions, and two Desk Offices, providing timely support and guidance to marine product exporters, processors, and aquaculturists. Additionally, the Rajiv Gandhi Centre for Aquaculture manages a Multi-Species Aquaculture Complex (MAC) at Kochi, which serves as a key facility for advancing aquaculture practices and technologies. This extensive organizational network ensures that the Authority remains accessible and responsive to the needs of stakeholders across the country.



Trade promotion offices

MPEDA has three Trade Promotion Offices, of which one is in New Delhi, mainly to liaise with various Ministries of Government of India. The other two offices are in New York and Tokyo. These Trade Promotion offices liaise with Importers, Government Agencies, Quarantine authorities, Trade Associations, etc. and keep a close watch on various developments within the country as well as their neighboring countries that may have an impact on the seafood trade from India.

Quality Control Laboratories & ELISA labs

MPEDA operates five full-fledged Quality Control Laboratories, at Kochi (Kerala), Nellore & Bhimavaram (Andhra Pradesh), Bhubaneshwar (Odisha) and Porbandar (Gujarat). These laboratories are equipped with sophisticated analytical instruments like LC-MSMS, GC-MSMS, ICP MS, HPLC, Automatic ELISA Analyser etc. for testing

chemical residues. All labs are accredited under ISO/IEC 17025 by the NABL (National Accreditation Board for Testing and Calibration Laboratories) and also recognized by EIC (Export Inspection Council) for testing Pre Export Test (PET) samples. Quality Control Lab at Kochi has a Microbiology division for testing bacteria and viruses. In addition to the samples under the monitoring plan, these labs also provide testing services for commercial samples of fish and fishery products.

In addition, fourteen ELISA Screening Laboratories and two collection centers are operated by MPEDA in the maritime states are performing the screening of aquaculture products for banned antibiotics like Nitrofurans Metabolites and Chloramphenicol prior to harvest. These labs are issuing Pre-Harvest Test (PHT) certificates for aquaculture products.

Societies

MPEDA has established three specialized societies to support different facets of the seafood and aquaculture sectors. The Rajiv Gandhi Centre for Aquaculture (RGCA) focuses on research and development activities aimed at enhancing export-oriented aquaculture. NETFISH, the Network for Fish Quality Management and Sustainable Fishing, operates at the grassroots level, empowering the fishing community through extension activities centered on fish quality management, conservation, and sustainable fishing practices. The National Centre for Sustainable Aquaculture (NaCSA) is dedicated to assisting aquaculture farmers in adopting sustainable and environmentally friendly farming methods, ensuring the production of high-quality and safe aquatic products. Together, these societies play a vital role in advancing research, community engagement, and sustainability within India's marine products industry.



(RGCA Head quarter at Sirkali, Tamil Nadu)

MPEDA's Milestones in Seafood Exports (2014–2025)

During the period MPEDA played a pivotal role in significantly advancing India's seafood export sector, particularly in shrimp exports. India's seafood export volume surged from 10.51 lakh MT to 16.85 lakh MT, while the export value saw an impressive 88% increase, rising from ₹33,441.61 crore to ₹62,897.86 crore, with a compound annual growth rate (CAGR) of 3.15%, outperforming the global average of 2.70%. The number of export destinations expanded from 105 to 130, and exporters increased from 1,196 to 1,276. Value-added product exports notably tripled, reaching ₹7,666.38 crore, supported by enhanced processing capacity that grew from 25,707 MT/day to 38,466 MT/day. Additionally, aquaculture production witnessed a remarkable growth of 180%, attaining 12.938 lakh MT.

MPEDA's initiatives addressed non-tariff barriers (NTBs), focusing on traceability, quality, and sustainability. Collaborating with the Ministry of Health and Family Welfare (MoHFW), MPEDA contributed to banning the use of antibiotics such as Chloramphenicol and Nitrofurans in food-producing animal rearing systems, which were major causes of shrimp consignment rejections in international markets. The authority also facilitated export promotion by participating in 61 international seafood fairs, conducting 92 buyer-seller meetings across 37 markets, and leading 12 overseas delegations. Since 2018-19, MPEDA digitally validated over 3 lakh export facilitation certificates, helped remove trade restrictions imposed by countries like Qatar and China, and trained 1,529 personnel on Seafood HACCP standards, which contributed to reducing overall rejections from 84 in 2014 to 48 in 2024, including antibiotic-related rejections dropping from 34 to 21. Furthermore, MPEDA advocated for duty-free imports, regulatory reforms, and decriminalization of trade laws, bolstering India's seafood export competitiveness.

MPEDA's collaborative efforts with central government departments and regulatory agencies led to the introduction of the Turtle Excluder Device (TED) under the Pradhan Mantri Matsya Sampada Yojana (PMMSY) in partnership with the Department of Fisheries (DoF). It maintained close coordination with MoHFW on antibiotic bans, facilitated bilateral trade discussions, supported farm registrations with the Coastal Aquaculture Authority (CAA) and states, and assisted seafood facility inspections with Export Inspection Council (EIC). On the international front, continuous engagement with Japan's Ministry of Health secured an exemption for Black Tiger Shrimp from antibiotic import inspections.

In research and development, MPEDA supplied 85.4 million seeds of diversified species such as Tilapia, Seabass, Pearl spot, and Mudcrab to 13,730 farmers and screened 2.1 million broodstock shrimps at its Aquatic Quarantine Facility in Chennai.

The organization provided technical consultancy, signed 14 Memorandums of Understanding (MoUs), and partnered globally with institutions including NACA and SEAFDEC. Studies such as the water quality assessment of Ashtamudi Lake for clam certification and participation in seaweed park development in Tamil Nadu under PMMSY further demonstrate its commitment to sustainable growth.

Building stakeholder capacity has been a crucial focus area, with MPEDA supporting infrastructure development for 329 seafood processing units through ₹220.24 crore funding from 2014-15 to 2024-25, and granting ₹5.48 crore to 111 farmers for adopting better practices. It conducted 64 seafood value addition training programs, benefiting 2,655 processing workers between 2017-18 and 2024-25. India's response to the US Department of Labor in December 2024 outlined robust measures to protect labor rights in the shrimp sector. Additionally, MPEDA's outreach programs through NETFISH and NaCSA reached over 8.20 lakh stakeholders via 49,380 sessions, organized 211 coastal clean-ups, promoted sustainable fishing practices such as square mesh cod-end adoption by 725 vessels, and facilitated the formation of 945 farming clusters and 126 societies under NaCSA.

Among new initiatives, MPEDA launched quality and traceability programs like SHAPHARI certification and AquaTrace, enrolling 58,943 farms covering 1,13,633 hectares. It strengthened institutional collaborations with ICAR institutions, government bodies, and regulatory agencies, organizing three Chintan Shivir workshops (in Chennai, Goa, and Lakshadweep) to tackle sector challenges and boost exports. Scientific partnerships with ICAR-CIFT, FSI, CCMB, and CMFRI addressed trade barriers, such as developing TED to lift US import bans on wild-caught shrimps and conducting marine mammal stock assessments for compliance with US Marine Mammal Protection Act (MMPA). MPEDA also supported seafood sterilization during COVID-19 and explored resource utilization in the CCAMLR Antarctic fishing Regional Fisheries Management Organization (RFMO).

Collaboration with state fisheries departments has been instrumental in promoting TED adoption, advocating for mandatory TED use under Marine Fishing Regulation Acts, encouraging task force committees for aquaculture inspections, conducting training on trade regulations and lab techniques, and raising awareness on labor issues and protections. MPEDA's engagement with Indian Missions worldwide facilitated seafood exhibitions, buyer-seller meets, training, market studies, dispute resolution, technology transfer, and consultancy support for seaweed farming. Internationally, partnerships with agencies like the US FDA (Shrimp Regulatory Partnership Agreement and Seafood HACCP training), AIT, FAO, Globefish, and INFOFISH have supported capacity building and seafood industry

development. Lastly, the aquaculture technician program trained 303 technicians in best aquaculture practices, contributing to sustainable sector growth.

Overall, MPEDA's comprehensive approach encompassing export facilitation, quality assurance, regulatory collaboration, research, capacity building, and innovative initiatives has significantly propelled India's shrimp and seafood export sector, positioning it strongly in the global marketplace.

Over the years, particularly between 2014 and 2025, MPEDA has implemented significant reforms aimed at easing business operations and reducing the compliance burden for stakeholders in the seafood sector. Under the Jan Vishwas Bill, certain provisions of the MPEDA Act and Rules were decriminalized, making the regulatory framework more entrepreneur-friendly. New registration guidelines were introduced for handling facilities, ornamental fish units, and fish meal and fish oil units to streamline processes. Additionally, MPEDA submitted comprehensive guidelines for the registration of marine product dealers to the Department of Commerce, aiming to enhance traceability across the value chain. A major reform initiative has been the digital enrollment of coastal shrimp farms through a cutting-edge application called AquaTrace, which captures pond-wise details, geolocations, and ownership data using drone imagery to improve product traceability. Over the past decade, this initiative successfully enrolled 58,943 farms covering 1,13,633 hectares. Furthermore, MPEDA developed and implemented digitized platforms for registering entities, validating export facilitation certificates, monitoring quality, and conducting pre-harvest testing, greatly enhancing efficiency and compliance.

Reflecting on its journey over the last five decades—and with notable progress from 2014 to 2025—MPEDA has established itself as the backbone of India's seafood export ecosystem. By integrating robust policy support, global trade facilitation, rigorous quality assurance, farmer empowerment, and sustainability-focused initiatives, MPEDA has significantly expanded India's seafood export reach from 105 to 130 global destinations, nearly doubled the export value, and solidified India's position as one of the world's premier suppliers of shrimp and marine products. With forward-looking reforms such as digital farm enrollment, SHAPHARI certification, AquaTrace traceability, and strategic collaborations with global institutions, MPEDA has strengthened compliance with international standards and built resilience against non-tariff barriers. Its commitment to research and development, capacity building, and sustainable aquaculture ensures that growth is inclusive, environmentally responsible, and competitive on a global scale. As India embraces the vast potential of the Blue Economy, MPEDA continues to act as a catalyst for innovation, sustainability, and export excellence, firmly anchoring the nation's seafood sector in global markets and setting the stage for even greater accomplishments in the years to come.