TECHNOLOGICAL INTERVENTIONS FOR SUSTAINABLE AQUACULTURE





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Introduction

World population is around 8.03 billion and it is estimated to reach 9.7 billion by 2050 (UN, 2019). This increase in population will require a parallel rise in food production. Fish have been a staple food of the human diet even 40 millennia ago. Some hypotheses contend that fish consumption increased the size of the human brain and promoted the emergence of more complex social behaviour in humans, which ultimately helped our ancestors become the dominant species (Crawford et al., 1999; Broadhurst et al., 2002; Cunnane and Stewart, 2010).

More than 20 years have passed since we reached the maximum quantum of our ocean that could be exploited and there is only a very little window of opportunity to expand the capture fisheries in the ocean (Pauly et al., 2002). In order to meet the world's food demand over the next two decades, the aquaculture industry has to gear up to rise by more than 50% (FAO, 2020). This must be done in a way that is sustainable from an economic, social, and environmental standpoint. On the other hand, the need to feed the multibillion of people and the rising demand for animal protein pose a significant threat to nutritional security. According to "Agricultural Outlook 2012-2021" aquaculture is the best way to meet the fish demand by growing world population (OECD/FAO, 2012). Fisheries and aquaculture play a notable role in food production by providing 17% of the animal protein to almost 3.2 billion people (FAO, 2020).

Aquaculture

Aquaculture is defined by the Food and Agriculture Organization of the United Nations (FAO) as follows “Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture” (FAO 1997).

Objectives of aquaculture

- Production of low cost protein rich, nutritive, palatable and easily digestible human food.
- Providing new species and strengthening stocks of existing fish in natural and man-made water-bodies through artificial recruitment

- Production of ornamental fish for aesthetic appeal.
- Effective utilization of aquatic and land resource
- Recycling of organic waste of human and livestock origin
- Providing means of livelihood through commercial and industrial aquaculture.
- Production of sportfish and support to recreational fishing.
- Production of bait-fish for commercial and sport fishery.

Production of aquaculture

The total global fisheries production was estimated as 177.8 million metric tonnes in 2020, a slight decrease from the all-time high of 179 million tonnes in 2018 (FAO SOFIA, 2022). Aquaculture is a fast-growing food production sector. Aquaculture production exceeded capture fisheries production for human consumption in 2016 (FAO, 2020), and it contributed to 52% of the total aquatic animals for human consumption in 2018 (FAO, 2020). The total aquaculture production during the year 2020 was 87.5 million tonnes (49%), of which crustaceans contributed to 11.2 million tonnes (9.2%) (FAO SOFIA, 2022). Among the crustaceans, *Penaeus vannamei* contributed around 52.9% in 2018 (FAO, 2020). According to FishStatJ, the world production of farmed *P. vannamei* was 5,812,180 t in 2020. The production records of *P. vannamei* compiled by FAO indicate that the cultivated biomass increased 37.6 times worldwide during the period 2000-2020.

Scope of aquaculture

Current aquaculture technology allows the commercial and viable production of a number of organisms through the management of their entire life cycles. The “seed” materials (larvae and juveniles) are produced under controlled conditions, starting from the maturation of broodstock, which eliminates the need for the collection of juveniles from the wild. Aquaculture involves a thorough understanding of the behavior, habitat and environmental requirements, reproductive biology, nutritional requirements, and larval and juvenile physiology of each species, as well as its susceptibility to disease under culture conditions. Moreover, it involves the development of all aspects of fish husbandry, such as the facilities required for the various life-cycles stages like broodstock holding tanks/sea cages, nursery tanks/cages, grow-out facilities, feed development, fish handling systems, and disease control. Such procedures and techniques have been developed for several marine fish, estuarine and fresh water fin fishes and shell fishes.

Fisheries is a sunrise sector in Indian agriculture, with high potentials for diversification of farming practices, rural and livelihood development, domestic nutritional security, employment generation, export earnings as well as tourism. The possibilities extend from vast seas to high mountains with valued coldwater species. Untapped potentials exist in island systems from ornamental fishes to value added products. This sector provides employment opportunity to 5 million fisher peoples from coastal villages, major river basins and reservoirs in the country. Of the countries bordering Indian ocean, India is endowed with coastline length of 8,129 km, 2.02 million sq km of Exclusive Economic Zone (EEZ) comprising 0.86 million sq km on the East coast, 0.56 million sq km in the West coast and 0.60 million sq km around Andaman and Nicobar Island and 0.5 million sq km of continental shelf with a annual catchable marine potential of 3.93 million tons. Besides, there are vast brackish water areas all along the coast line which are suitable for seafarming and mariculture.

The freshwater aquaculture systems in the country has primarily confined to three Indian major carps, viz., rohu, catla and mrigal, with exotic species: silver carp, grass carp, and common carp forming the second important group. Among the catfishes, magur (*Clarias batrachus*) has been the single species that has received certain level of attention both from the researchers and from farmers due to its high consumer preference, high market value and most importantly its suitability for farming in shallow and derelict water bodies with adverse ecological conditions. Recent years, however witnessed increasing interest for farming of *Pangasius* spp., especially in Koleru lake region of Andhra Pradesh due to its higher growth potential and ready market. Other potential species include *Labeo calbasu*, *Labeo gonius Labeo bata*, *Labeo dussumeri*, *Labeo fimbriatus*, *Barbodes carnaticus*, *Puntius pulchellus*, *Puntius kolus*, *Puntius sarana*, and *Cirrhinus cirrhosa*. Some of these species are being cultured at a very low level in different parts of the country, mostly based on wild seed collection. The freshwater air-breathing and non air-breathing species, *Channa marulius*, *Channa striatus*, *Channa punctatus*, *Channa gachua*, *Channa stewartii* have not been taken up for the aquaculture activities in serious way. With the technology available for seed production and culture of air breathing (*Clarias batrachus*, *Heteropneustes fossilis*) and non air breathing catfish like (*Wallago attu*, *Mystus seenghala*, *Mystus aor*, *Horabagrus brachysoma*, *Pangasius pangasius*), scientific organized catfish farming can be taken up in extensive and semi intensive way (Ponniah and Sundaray, 2008). The giant freshwater prawn, *Macrobrachium rosenbergii* has been the principal species, adopted both under monoculture and under mixed farming of freshwater prawn production of about 43,000 tonnes in the country at present. However, *M. malcomsonii* and *M. gangeticum* have not been taken up in a big way

In the brackishwater sector, the aquaculture development is mostly contributed by shrimp, *Penaeus monodon* culture only. The other shrimp species like *Fenneropenaeus indicus*, *Fenneropenaeus merguiensis*, *Penaeus pencillatus*, *Marsupenaeus japonicus* and *Penaeus semisulcatus* are not cultured on a commercial level large-scale culture. Recently *Fenneropenaeus vannamie* culture is developing in India. The finfish species like the seabass (*Lates calcarifer*) and grouper (*Epinephelus* spp.), grey mullet (*Mugil cephalus*), pearl-spot (*Etroplus suratensis*), milk fish (*Chanos chanos*) which are promising and ideal for aquaculture has not been exploited. The potential marine finfish species are *Epinephelus malabaricus*, *Epinephelus coioides, Epinephelus tauvina, Epinephelus fuscoguttatus, Epinephelus polyphekadion, Cromileptis altivelis*, *Rachycentron canadum*, *Seriola quinqueradiata*, *Trachinotus blochii*, *Coryphaena hippurus*, *Psettodes erumei, Lutjanus argentimaculatus*, and *Pampus argenteus*. Mariculture is expected to be a major activity in the Indian coastal areas in the years to come. Given the wide spectrum of cultivable species and technologies available, the long coastline and favorable climate, mariculture is likely to generate considerable interest among the coastal population and entrepreneurs.

In the present era of food insecurity, aquaculture shows enormous potential to feed not only the ever increasing human population but also the aquaculture products can be utilized as a feed ingredient in the diets of different domesticated animals of high commercial value. The aquaculture sector has become a modern, dynamic industry that produces safe, high valuable and high quality products, and has developed the means to be environmentally sustainable aquaculture is currently the need in India as elsewhere. Eco-friendly aquaculture in harmony with environmental and socioeconomic needs of the society has to be evolved.

ORNAMENTAL FISHERIES: RECENT INITIATIVES BY THE GOVERNMENT OF INDIA

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Introduction

In recent years, national and international forums have paid a lot of attention to the sustainability and conservation of our aquatic ecosystem, which is made up of a variety of freshwater ecosystems and encompasses more than 70% of the planet's surface in the form of oceans and seas. Additionally, it supports important economic sectors like tourism and fishing. But today, numerous actors are constantly posing serious risks to these habitats. The Department of Fisheries, Ministry of Fisheries, Animal Husbandry and Dairy, Government of India sincerely acknowledges the necessity of protecting these habitats while ensuring the best possible use of our national resources. The sector of fisheries and aquaculture keeps environmental sustainability as the primary focus.

In light of this, the Department is implementing several programmes and initiatives that aim to expand the fisheries and aquaculture industries while placing a strong emphasis on environmental sustainability. For improving production and productivity in ornamental aquaculture, input support and facilities such as brood banks, hatcheries, rearing facilities, and quality seed units will be supplied. Support will be provided for the establishment of extension support services as well as the infrastructure and processes for the certification of seeds and feed, input quality testing, and aquatic animal health management, including quarantine.

India contributes very little to the global ornamental fish market. Support under PMMSY will be given for the cultivation of ornamental fish through the necessary interventions, such as the establishment of production units, the introduction of commercially significant exotic species, the import of breeding technology, and the extension of technological, marketing, and logistical support to entrepreneurs. Aquaparks are suggested under PMMSY as centres for a variety of fisheries activities and amenities that address different phases and parts of the value chain for fisheries and aquaculture. Aquaparks can serve as hubs for a variety of activities, including the production of high-quality feed and seed, pre- and post-harvest infrastructure, business and commerce, marketing, and export promotion. Additionally, aqua parks could be built using a hub-and-spoke design that integrates clusters and areas with comprehensive solutions tailored to regional requirements and particular themes.

Blue Revolution

The Department's flagship programme, "Blue Revolution" was introduced in 2015 to achieve economic prosperity for the nation, fishers, and fish farmers, as well as contributing to food and nutritional security through the sustainable development of fisheries while taking biosecurity and environmental concerns into consideration. Under Blue Revolution, a total of Rs. 2573 crores in central funding was made available to various States, Union Territories, and organisations to promote environmentally friendly aquaculture practices while also fostering the sustainable and all-encompassing development of fisheries and the welfare of fishermen.

The export potential for ornamental fisheries is enormous; it is a $10 billion business with a multibillion-dollar retail sector that spans more than 125 nations. The Department is working towards the comprehensive development of the industry through the establishment of ornamental fish clusters in specific inland and marine areas to position India at the forefront of ornamental fisheries. To make the industry dynamic and lucrative, emphasis is also being placed on developing public-private partnerships for the creation of various fish-producing units.

The programme has already begun showcasing palpable advantages by utilizing a participatory strategy. Accordingly, the following sanctions for an investment of Rs. 15.3 crores in FY 20-21 were made. By FY 2024–2025, the Departments plan to create 2,121 backyard, integrated, and medium-sized ornamental fish rearing units in both marine and freshwater, as well as 10 ornamental fish brood banks, fish retail markets, and fish kiosks.

Salient Features of the Blue Revolution Scheme

- Providing suitable linkages and convergence with the 'Sagarmala Project' of the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNAREGA), Ministry of Shipping, National Rural Livelihoods Mission (NRLM), Rashtriya Krishi Vikas Yojana (RKVY), etc.
- The Blue Revolution scheme concentrates mainly on enhancing the production and productivity of aquaculture and fisheries both from the inland and marine sources.
- Promoting and encouraging the economically backward sections like the Scheduled Castes, Scheduled Tribes, Women, and their co-operatives to take up fishing.
- The Blue Revolution Scheme promoted the growth of entrepreneurship, private investment, and improved institutional financial leveraging.

The pattern of financing and system for implementation

The programme was put into action in accordance with the annual budgetary allocation in the Ministry of Agriculture and Farmers Welfare's Demand for Grants and the Administrative Approval dated May 20, 2016. In response, the participating State Departments, Agencies, Institutions, and Beneficiaries have received financial support from the DOF. The pattern of assistance followed any alterations or modifications that the GOI made from time to time.

The goal of the Blue Revolution is to create the conditions necessary for the integrated development of the nation's fisheries while also significantly raising the income levels of fishermen and fish farmers while taking sustainability, biosecurity, and environmental concerns into consideration.

The National Fisheries Development (NFDB)

In order to take advantage of the significant untapped potential in fisheries and aquaculture in the country, the National Fisheries Development Board (NFDB) was established as a Registered Society in Hyderabad on July 10, 2006, under the administrative control of the Department of Animal Husbandry, Dairy and Fisheries, Ministry of Agriculture, Government of India. The main objectives of the NFDB are to increase fish production and productivity as well as strengthen infrastructure facilities to support the overall development of the fisheries industry.

Schemes for ornamental Fisheries by the NFDB

• Ornamental fish production – Backyard hatcheries for women SHGs/ Fisher women cooperatives/ other house holds

• Medium-scale unit for ornamental fish production by the entrepreneurs

• Integrated ornamental fishery units with hatcheries for ornamental fishes

• Setting up of Aquarium fabrication units - women SHGs / Fisher women cooperatives/ others

• Training and demonstration to the beneficiaries of the scheme.

(i) Backyard hatcheries for Ornamental fish production

Members of women's SHGs or fisherwomen cooperatives, as well as any household with a primary residence and at least 200 to 250 square feet of vacant land with the necessary water infrastructure to set up an ornamental fish production plant. Members of women's SHGs or fisherwomen cooperatives, as well as any household with vacant land close to their home that is leased for at least 7 years and has a minimum area of 200 to 250 square feet and suitable water facilities.

- Willingness to engage in the activity following NFDB regulations
- Potential beneficiaries who are eager to enrol in training programmes at establishments supported by the government.

(ii) Medium-scale ornamental breeding and rearing unit

Entrepreneurs having owned a minimum area of approximately 300 mts vacant land with adequate water facility for setting up of ornamental fish production unit.

- Willing to take up the activity under the guidelines of NFDB
- Prospective beneficiaries willing to undergo training at Government sponsored institutions.

(iii) Integrated ornamental fishery units

State Fisheries Department / Fisheries corporations / Federations/ICAR institutions having own land and water facilities adequate to set up the unit. The land along with the water facility may be hired on a lease basis with a minimum period of 7 years.

- The private entrepreneurs have owned a minimum land area of 1000 sq ft and a water facility for setting up integrated ornamental units.
- Willing to take up the activity by the guidelines of NFDB.
- Prospective beneficiaries willing to undergo training at Government sponsored institutions.

(iv) Aquarium fabrication units

Members of Women SHGs /fisherwomen cooperatives and any individual having owned the adequate vacant place for setting up fabrication of aquaria unit as prescribed by the NFDB.

- Willing to take up the activity following the guidelines of NFDB.
- Prospective beneficiaries willing to undergo training at Government sponsored institutions.

Pradhan Mantri Matsya Sampada Yojana (PMMSY)

The PMMSY is intended to address significant gaps in fisheries management, traceability, post-harvest infrastructure and management, quality, technology, and fishers' welfare. It is also planned to modernise and improve the value chain. The PMMSY is an umbrella scheme with two separate components namely

(a) Central Sector Scheme (CS) and

(b) Centrally Sponsored Scheme (CSS).

The Centrally Sponsored Scheme (CSS) Component is further segregated into Non-beneficiary oriented and beneficiary-orientated subcomponents/activities under the following three broad heads:

(i) Enhancement of Production and Productivity

(ii) Infrastructure and Post-harvest Management

(iii) Fisheries Management and Regulatory Framework

Pradhan Mantri Matsya Sampada has been approved at a total estimated investment of Rs. 20,050 crores comprising of Central share of Rs. 9407 crores, State share of Rs 4880 crores and Beneficiaries contribution of Rs. 5763 crores.

PMMSY will be implemented in all the States and Union Territories for 5 years from FY 2020-21 to FY 2024-25

Funding Pattern

Central Sector Scheme (CS)

The entire project/unit cost will be borne by the Central government (i.e. 100% central funding. Wherever direct beneficiary oriented i.e. individual/group activities are undertaken by the entities of central government including the National Fisheries Development Board (NFDB), the central assistance will be up to 40% of the unit/project cost for the General category and 60% for SC/ST/Women category.

Centrally Sponsored Scheme (CS)

For the Non-beneficiary orientated sub-components/activities under the CSS component to be implemented by the States/UTs, the entire project/unit cost will be shared between the Centre and State as detailed below:

(a) North Eastern & Himalayan States: 90% Central share and 10% State share.

(b) Other States: 60% Central share and 40% State share.

(c) Union Territories (with the legislature and without legislature): 100% Central share.

For the Beneficiary orientated i.e. individual/ group activities subcomponents/ activities under CSS component to be implemented by the States/ UTs, the Government financial assistance of both Centre and State/ UTs governments together will be limited to 40% of the project/unit cost for General category and 60% of the project/unit cost for SC/ST/Women. The Government financial assistance will in turn be shared between the Centre and State/UTs in the following ratio:

(a) The North Eastern & the Himalayan States: 90% Central share and 10% State share.

(b) Other States: 60% Central share and 40% State share.

(c) Union Territories (with the legislature and without legislature): 100% Central share (No UT Share).

The sharing funding pattern for this activity under the PMMSY is summarized as below:

STATES/ UT	FUNDING PATTERN	CONTRIBUTION
General states	50:50 centre and general states	Centre share Rs. 1500 + state share Rs. 1500 + Beneficiary share Rs. 1500=Rs. 4500/year
North east and Himalayan states	80:20 Centre and NE & Himalayan states	Centre share Rs. 2400 + state share Rs. 600+ Beneficiary share Rs. 1500= Rs.4500/year
Union Territories	100 % as centre share for UTs	Centre share Rs.3000 + Beneficiary share Rs. 1500= Rs.4500/year

Development of ornamental and recreational fisheries

Sub component and activities	Unit	Unit Cost (Rs. Lakh)	Government assistance (Rs. Lakhs)	
			General (40%)	SC/ST/Women (60%)
Backyard Ornamental fish rearing unit (both marine and freshwater)	Nos	3.00	1.20	1.80
Medium scale Ornamental fish rearing unit (both marine and freshwater)	Nos	8.00	3.20	4.80
Integrated Ornamental fish unit (breeding and rearing for freshwater fish)	Nos	25.00	10.00	15.00
Integrated Ornamental fish unit (breeding and rearing for marine fish)	Nos	30.00	12.00	18.00
Establishment of freshwater Ornamental Fish Brood Bank	Nos	100.00	40.00	60.00
Promotion of recreational fisheries	Nos	50.00	20.00	30.00

Markets and Marketing Infrastructure

Sub component and activities	Unit	Unit Cost (Rs. Lakh)	Government assistance (Rs. Lakhs)	
			General (40%)	SC/ST/Women (60%)
Construction of fish retail markets including ornamental fish/ aquarium markets	Nos	100.00	40.00	60.00
Construction of fish kiosks including kiosks of aquarium/ ornamental fish	Nos	10.00	4.00	6.00
E-platform for e-trading and e-marketing of fish and fisheries products	Nos	25.00	10.00	15.00

The Marine Products Exports Development Authority (MPEDA)

The MPEDA Act of 1972's Section (4) established the Marine Products Export Development Authority (MPEDA), which went into operation on April 20, 1972. Under the Department of Commerce, it is a statutory entity. Specifically concerning exports, the MPEDA, a statutory entity, is in charge of developing the marine goods sector. A Chairman oversees it. There are numerous Regional and Sub-Regional Offices, and its main office is in Kochi. The export of marine products increased by around 30% from FY 2020–21 to FY 2021–22, reaching an all-time high of US$ 7.74 billion. In terms of US$ profits, exports from April to

September of FY 2022–23 increased by 6.67% as compared to the same period in the previous year. The United States, China, and Japan make up the bulk of the nation's seafood exporters.

Funding schemes available from MPEDA

Recently the Marine Products Exports Development Authority (MPEDA) launched a subsidy scheme for the setting up of ornamental fish breeding units to facilitate foreign exchange. Under this scheme MPEDA provides

(i) Subsidy for the ornamental fishery to registered self-help groups and societies.
(ii) Support livelihood and promote foreign trade.
(iii) Financial assistance is provided at the rate of 25% of the total investment, subject to a maximum of Rs 10 lakh.

The MPEDA has also launched a Green Certification scheme, the first of its kind for the freshwater ornamental fishery, to curb the harmful impact of wild capture of aquarium fishes and help maintain environmental and economic sustainability.

Green certification

Green Certification for sustainable development is an emerging concept in the case of fresh water ornamental fish. The International workshop organized by the Marine Products Export Development Authority (MPEDA) in association with United Nations Conference on Trade and Development (UNCTAD) and Project PIABA, Brazil, at Kochi, India from14 – 18 October 2008 is the first of its kind in the world. Consequently, the National level Task Force constituted for preparing the Guidelines for Green Certification of ornamental fishes has come out with the Guidelines and Geographical Indication of selected species after a series of brainstorming sessions and deliberations. The findings of the Task Force can be briefly summarized as follows:

- The ornamental fish sector is being operated in an unorganized manner at present with minimum scientific inputs and national policy involvement. This could be improved once the green certification system is introduced for an effective value chain system.
- The increasingly stringent export standards of the buyers call for a systematic and efficient mechanism for monitoring and surveillance of the chain of custody to issue the necessary certificates by the authorities concerned. The Green certification and Green Seal Labelling would assure an eco-friendly healthy fish to the buyer.
- The importance of maintenance of log books and records at all stages of the value chain is emphasized and the necessary proforma have been appended to the report.
- The floor plans for different facilities to maintain high standards in the handling and care of the fish are appended.

- These guidelines may be implemented to encourage voluntary participation of all stake holders.
- Standards for assessment and necessary score cards for evaluation for the award of Green Certification have been developed.
- A list of endemic freshwater ornamental fishes has been identified, as these have the potential for registration under the GI Act, 1999 (Govt. of India).

The MPEDA as the nodal agency has taken appropriate action to implement Green Certification and Green Seal Labelling for Freshwater Ornamental Fish of the country.

Central Marine Fisheries Research Institute (CMFRI)

The ICAR-Central Marine Fisheries Research Institute was established by the Government of India on February 3rd 1947 under the Ministry of Agriculture and Farmers Welfare and later it joined the ICAR family in 1967. During over 75 years the Institute has emerged as a leading tropical marine fisheries research institute in the world.

Since its inception, the CMFRI grew significantly in size and stature and built up adequate research infrastructure and recruited qualified staff. During the first half of the five decades of its existence, the CMFRI devoted its research attention towards the estimation of marine fisheries landings and effort, the taxonomy of marine organisms and the bio-economic characteristics of the exploited stocks of finfish and shellfish. This research effort contributed significantly to India's marine fisheries development from a predominantly artisanal, sustenance fishery till the early sixties to that of a complex, multi-gear, multispecies fishery. The Institute's multidisciplinary approach to research in marine capture and culture fisheries has won its recognition as a premier institute comparable to any well-established marine laboratory in the world.

Contribution of the Central Marine Fisheries Research Institute (CMFRI) in the ornamental fish industry:

The Central Marine Fisheries Research Institute (CMFRI) has been focusing on this vital aspect of this low-volume and high-value industry for the past few years. These investigations made by CMFRI have resulted in the development of hatchery technology for 21 species of marine ornamental fishes such as

- **Clown fishes**
    - (i) *Amphiprion percula* (True percula/ clown anemone fish);
    - (ii) *A. ocellaris* (Common Clown/False clown aenemone fish);
    - (iii) *A. sandaracinos* (Yellow Skunk Clown);
    - (iv) *A. frenatus (*Tomato clown),
    - (v) *A. clarkii* (Clark's anemone fish),
    - (vi) *A. sebae* (Sebae clown)

(vii) *A. periderarion*(Pink anemone fish)

(viii) *A. ephippium* (Red saddle back anemone fish),

(ix) *A.nigripes* (Lakhadweep clownfish),

(x) *Premnas biaculeatus* (Maroon clown/ Spine cheek) anemone fish.

- Damsels

  (i) *Dascyllus trimaculatus* (Three spot damsel);

  (ii) *D. aruanus* (Striped damsel);

  (iii) *Pomacentrus caeruleus* (Blue damsel);

  (iv) *P. pavo (*Sapphire or Peacock Damsel);

  (v) *Neopomacentrus nemurus (*Yellow tail damsel);

  (vi) *N. filamentosus* (Filamentous tail damsel)

  (vii)*Chrysiptera cyanae* (Sapphire devil);

  (viii) *C. unimaculata* (One spot damsel),

  (ix) *Chormis viridis* (Green chromis), and also

- Dotty back *Pseudochromis dilectus* (Redhead Dottyback),
- **Purple fire goby *Nemateleotris decora* for the first time in the world**.

The complete package of practices developed for their production can be taken up as an alternative livelihood option for small and large-scale fish farmers. The transfer of technology to the public and private sector entrepreneurs who have approached the technology is being planned by imparting hands-on training through different modes under the Consultancy Processing Cell (CPC) of the CMFRI and organized training. In addition, the hatchery-produced seeds are also being sold to the farmers and aquarium hobbyists and traders through Single Window System and seed counters are in operation on marine hatcheries of CMFRI at Cochin and Mandapam. This has resulted in the emergence of several ornamental fish trade shops all over the country.

All India Network Project on ornamental fish breeding and culture

To fully utilize the potential resources offered by India, there must be strong ties between researchers and industrial partners in the country's ornamental fish sector. Therefore, the Ministry of Fisheries, GOI, established a project on All India networking of ornamental fish breeding and culture.

The construction of decorative fish settlements with strong marketing linkages is one of several goals the initiative has in mind. The project is focused on creating a value chain approach from seed collecting, culture, and export of numerous ornamental variations while maintaining product quality, global access to the Indian ornamental fish industry, and environmental and socioeconomic sustainability. The project's main focus on technology for ornamental fish breeding and culture will create jobs and additional income for individuals in both urban and rural areas. One of the intended outputs of the project is the establishment of regional hatchery units and satellite hatcheries under the public-private partnership (PPP) format.

The ICAR research institutes namely, Central Institute of Freshwater Aquaculture (CIFA, Central Inland Fisheries Research Institute (CIFRI); National Bureau of Fish Genetic Resources (NBFGR); Central Institute of Brackishwater Aquaculture (CIBA); Central Institute of Fisheries Education (CIFE); and Directorate of Coldwater Fishery Research (DCFR) are the other partners in the network project.

Conclusion

Ornamental fish farming can be adopted anywhere in the country as an option to enhance and support livelihoods. In addition to helping to build commercial small-scale farming under a difficult climatic regime (low and high temperatures), the establishment of local farms will aid in the customization of ornamental fish farming to meet local conditions and minimal investment needs.

More opportunities for women must be established, primarily through the gathering and sharing of knowledge and the transfer of technology between various regions of our state and nation. Due to the modest space and financial requirements, ornamental fish farming might be a potential solution for many self-help organizations. The success of women in starting home-based ornamental fish farming companies is motivating other self-help organizations to start their own. Additionally, the government recently announced that special packages could be offered to unemployed women to help them start ornamental fish farming.

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BREEDING AND REPRODUCTION OF COMMERCIALLY IMPORTANT ORNAMENTAL FISHES

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Live bearers

They give birth to young ones and produce only few numbers of offspring in comparison to egg layers. Their breeding is relatively easy and development of young ones takes place inside the female, which are released after about 4 weeks. The common livebearers include guppy, molly, swordtail, and platy. The number of offspring produced by livebearers is between 50-100. If properly fed with natural food, supplemented with better artificial feed, the mortality caused by predation or cannibalism could be checked thereby survival rate of these offspring can be increased.

Breeding

Unlike other fishes, female livebearers are fertilized internally by transferring milt to females by means of the males modified anal fin, the gonopodium. Breeding pattern of guppies and other fishes of this group vary.

Guppy (*Poecilia reticulate*)

Male guppy reaches up to 2.5 – 3.5 cm length, while the female is usually larger when fully grown. They thrive in a large well-planted tank with temperatures within 20–25˚ C. Gravid females with their abdomen enlarged are collected and placed in the breeding tank (30 cm x 20 cm x 20 cm) individually or pairs. Plants like *Cabomba* can be placed in the aquarium. Once individual females give birth to 20-200 young ones, the tank is aerated. For mass breeding of guppy a tank size of 100 cm x 100 cm x 60 cm is ideal, where a perforated cylindrical basket can be provided in one side of the tank encircled with fibrous plastic flowing filaments where the female can drop the young ones. Soon after birth, the young ones escape from their mother and enter into the perforated basket and later the young ones are collected from the basket and placed in separate tanks, for further rearing.

Platy, Swordtail and Molly

The platies and swordtails (*Xiphophorus spp.*) take 6-8 weeks, while mollies (*Poecilia spp.*) take 12-16 weeks to mature. These fishes also have gonopodium with which milt is released into female and eggs are fertilized inside the mother's body. After fertilization, the embryo grows to tiny young ones and becomes ready for free swimming within 4 weeks of gestation period. Platies, swordtails and mollies are quite hardy fish; they will breed well in most type of water, as long as it is not too soft or acidic. Addition of little aquarium marine salt or common salt to water (0.5 –1 g/litre) is beneficial for mollies.

Breeding table of livebearers

Species	Sexual dimorphism	Size	Optimum water condition for breeding	Gestation period (days)	Young ones/ females
Guppy, *Poecilia reticulate*	Male is smaller with more flowing fins and pointed anal fin or gonopodium	Male 2.5-3.5 cm; female 5-6 cm	Temp: 20-28˚ C, water hardness: 50-100 mg $CaCO_3$/litre (moderately soft water)	21-35	20-100
Platy, *Xiphophorus maculatus*	Male is smaller and slimmer with gonopodium.	Male 3-4 cm; female 4-5 cm	-do-	28-42	10-100
Sword tail, *Xiphophorus helleri*	Male is smaller and slimmer with gonopodium and pronounced sword like projection on caudal fin	Male 6-7 cm; female 7-9 cm	-do-	28-42	20-100
Black molly, *Poecilia sp.*	Male with gono podium, dorsal fin is flowing and bigger. Males are smaller than females and slimmer also	Male 7-8 cm; female 9 cm	Temp. 23-28˚ C, Aquarium salt at 0.5-1.0 g/litre	40-70	30-70

Egg layers

Important group of egg-layers are barbs, rasboras, goldfish, tetras, danios, betas, angel fish and gourami. Among them barb is one of the most important group. Barbs of Indian origin are rosy barb, striped barb and aruli barb. The major group of danios includes giant danio, pearl danio and zebra danio. Among rasboras slender rasbora, glowlight rasbora and scissortail are the important ones. Goldfishes are the most preferred fish for the aquarium keepers. Some common varieties being comet, lion head, oranda, red cap, veil tail, shubunkin, bubble eye etc. The fish grows up to 20 cm in length, but starts breeding when it is only 6 cm long.

The tetras are small fishes of 3-8 cm length that originated from South America. Most common varieties are the black widow tetra, flame tetra, neon tetra and cardinal tetra. The species, *Betta splendens*, popularly known as Siamese fighter, occurs in varied colours. The males become aggressive in presence of other males. Angelfish is an important group of aquarium fish with different varieties such as black, veil tail, marble and albino. Among gourami, three-spot gourami, pearl gourami, moonlight gourami, giant gourami and kissing gourami are the important species.

Breeding

During spawning period the female releases eggs in the water and the male simultaneously release milt close to the eggs. The eggs are thus fertilized outside the body of the female (external fertilization). Based on the type of incubation, egg laying fishes are further classified into five.

a. Egg scatterers laying non-adhesive eggs

Zebra fish (*Danio spp.)* is considered as egg scatterer, which lays non-adhesive eggs. Like many aquarium fishes, zebra fish also eats away its own eggs and spawn after breeding. As the precautionary measure, the bottom of the aquarium should be loaded with a layer of round pebbles of about 6-8 cm diameter. The breeding pair has to be well fed with live food like small zooplanktons.

During breeding the male female ration should be maintained at 2:1 or 3:1. The female is introduced in the breeding tank one day earlier than the males. The eggs require 2-3 days hatching time, if the temperature is favourable. As soon as the tiny hatchlings are seen in the aquarium tanks the parents are to be removed. The hatchlings take 2 days to absorb their yellow yolk sac. After 2 days, they are fed with infusorians for 4 days. Subsequently rotifers and smaller zooplanktons can be fed for 1 week, after which they can be provided with powdered formulate feed.

b. Egg scatterers laying adhesive eggs

Gold fish (*Carassius spp.*) is considered as egg scatterer laying adhesive eggs. When secondary sexual characters appear, the male and female gold fishes are selected and kept in circular glass tanks (24’’x 12’’x 15’’) or ferro-cement tank (3.5 ft. x 2.5 ft.) after disinfecting the containers with 1 ppm solution of potassium permanganate. The water used should be a mixture of ground and filtered pond water. The tanks should be placed where some early morning sunshine and no sunlight afterwards fall. Since goldfish eggs are sticky in nature, they require a surface to adhere. For this various artificial nets or submerged aquatic plants such as *Hydrilla* can be used. The nets should float close to the surface of water. The water temperature should be maintained between 20 and 30˚ C.

The spawner and milter in the ratio of 1:2 are released into the breeding tank in the late evening hours. Egg laying usually takes place within 6-12 hrs. When spawning is over nets should be transferred to a different container, or parent fishes are removed from the breeding tank. Generally a female lays about 2000- 3000 eggs. Healthy eggs are golden transparent at the beginning and gradually the transparency decreases. Unfertilized eggs will remain opaque. Under ideal condition, within 3 days, the eggs hatch-out with a hatching rate of 80-90%. When the young larvae start to float the nets and aquarium plants can be removed.

c. Egg depositors

Barbs (*Rasbora spp.*), small fishes that move in groups are ideal for a well-planted community aquarium. A temperature between 25° and 28° C is optimum for their breeding. They are difficult to breed but can lay up to 250 eggs/female. Like barbs they require soft, slightly acidic (pH 5.5) environment. After conditioning, male and female are placed in a tank planted with flat leaved plants. Once spawning occurs, remove both parents from the breeding tank. The eggs laid on the underside of the flat leaves will hatch after 24-36 hr and the resultant hatchlings become free swimming after 3-5 days. At this stage, the tiny hatchlings should be fed infusorians and newly hatched brine shrimp. As they grow bigger they should be fed zooplanktons, like *Moina* and *Daphnia*.

Angelfish (*Pterophyllum spp.)*

The mature angelfish having straight top and bottom fins without any bowing or bend is selected. They should be healthy, strong, robust and active. Unfortunately it is very difficult to differentiate between a male and female angelfish externally. In the beginning, 6-8 potential breeders are selected which can be set in a 100-litre tank and they are fed well with live food. The fish soon make pairs and start displaying breeding and courtship behavior. They spawn on broad-leaved Amazon sword plants in the aquarium. Angelfish prefer water with a 6.0–8.0 pH, with 6.5-7.4 being ideal, a water hardness of 50–130 ppm, and a temperature range of 24–30° C.

The female will deposit a line of eggs on the spawning substrate, followed by the male who will fertilize the eggs. This process will repeat itself until there are a total of 100-600 eggs. The pair will take turns maintaining a high rate of water circulation around the eggs by swimming very close to the eggs and fanning the eggs with their lateral fins. In a few days, the eggs will hatch and the fry will remain attached to the spawning substrate. During this period, the fry will not eat and will survive by consuming the remains of their yolk sacs. At one week, the fry will detach and become free-swimming. Fry can now feed on brine shrimp and after 2 weeks feed on powdered artificial feed.

d. Egg buriers

Among the egg buriers, the killi fish (*Aplocheilus spp.*) is the most important. They lay their eggs in a soft peat at the bottom of the tank or in densely planted aquarium tanks. They are good jumpers; therefore, they should be kept in covered aquarium. The eggs are capable of remaining viable even under dried condition and hatching may be possible even after some weeks or months, when placed again in water. In drought condition, parents may die but their eggs remain alive until the next rain. They rarely grow up to 3-4 cm in total length and are short lived.

e. Nest builders

The common nest builders are Gourami, Siamese fighter and Angelfish. They are bubble nest builders and incubate their eggs in floating nests, specially made by the male fish.

Gourami (*Osphronemus spp.)*:

Among the nest builders gourami is the most popular. For breeding purposes males and females are kept separately in different tanks for a week and fed with live food. When the abdomen of female becomes grossly, distended with eggs it is transferred to a smaller breeding tank with water level of 5-6" at 28-30˚ C. The tank should contain plenty of fine-leaf plants such as *Cabomba* and some floating plants. The water hardness of 100-200 ppm and pH of 7.0-7.5 are ideal.

After 1-2 days, mature male is introduced in the breeding tank. A transparent perforated plastic sheet or a glass is covered over the tank to keep the humidity and temperature at high level, which help to maintain the bubble nest in good condition. The male soon begins to build the bubble nest. This is possible by engulfing a large gulp of air at the water surface and converting it into many smaller bubbles that are passed into gill chamber and coated with an anti-burst agent before release.

After making the nest, the female deposits a large number of eggs in the nest. After breeding, female is removed, while males guard the nest. Hatching takes place within 24-36 hr and the moment fry swim freely from the nest, males are removed from the tank. The young ones are given infusorians at this stage and after a week newly hatched artemia and small cladocerans are provided. As they grow they accept all kinds of prepared feeds.

Siamese fighter (*Betta splendens)*

Adult fish attain sexual dimorphism at a length of 6 cm. It is best to attempt breeding with fishes that are about 9-12 months old. Allow one male to every 2 or 3 females. Females should be at least the same size as the male. Males are kept in small aquaria of 2-5 litre capacity, while females are kept in tanks containing 25-50 litres of water. Another breeding tank containing 50 litres water (depth 15 cm) and having leaf plants like *Myriophyllum* and *Cabomba* is required. The tank has to be partitioned into two using fine mesh net. In one half females and other half male fish is placed. Water temperature is maintained at around 27°C.

The male starts building a bubble nest quite quickly and once this is underway, the partition net is removed. At this crucial stage male should accept the female, otherwise male starts vigorous display of chasing which ultimately leads to fin tearing of female. Fighters often spawn in early morning and within a few hours 200-300 eggs are laid. As the eggs are shed and fertilized, they sink to the bottom. Males then collect them in his mouth and spit them into the bubble nest. At the end of spawning females are removed and male is left to guard the nest for 3 days after which it is removed. The eggs hatch after 36-48 hr. The smaller fry become free swimming after 5 or 6 days during when they can be fed with infusorium and egg-yolk. After 3 or 4 days, frys generally accept fine dry foods. The temperature of the water should be warm at around 27° C.

STATUS AND OUTLOOK OF THE ORNAMENTAL FISH INDUSTRY IN INDIA

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Introduction

Ornamental fish culture, also known as aquariculture, is the culture of attractive, colourful and peaceful fish in closed-water systems. Ornamental fish are also called "living jewels". Ornamental fish production is an important part of the aquaculture industry. The ornamental fish business is also a currency earner and a job. It plays an important role in the economy of developed and developing countries. The entire ornamental fish industry, including supplies and feed, is estimated to be over $14 billion. It is an important economic activity in 125 countries with Global trade of approximately US$ 18-20 billion involving over 2500 fish species (60% freshwater & 40% marine).

Since the beginning of time, keeping ornamental fish has worked especially for hobbyists. The ancient Romans kept the first ornamental fish as pets in their homes. In England and Scotland, keeping ornamental fish became popular as early as the 18th century. The art of breeding beautiful fish based on colour, design and shape quickly spread throughout the world. As interest in fancy varieties of brightly coloured organisms grew, ornamental fish farming became a huge business. In recent years this hobby has spread all over the world. As a result, many countries in Asia and Europe have begun to catch and breed colourful, imaginative and exciting fish breeds. More and more marine, brackish and freshwater fish were domesticated and popularized for commercial purposes.

Ornamental fish are the most popular pets in the world, and keeping fish is a popular hobby along with photography. The magnificent shapes and brilliant colours of ornamental fish have captured the hearts of millions of people; therefore, they can be aptly called 'living gems'. More than 120 countries are engaged in the ornamental fish trade, and there are approximately 1,800 species of ornamental fish on the market, of which more than 1,000 varieties are of freshwater origin, 90% of freshwater fish are farmed, and 10% are collected from the wild.

International market

The global ornamental fish market was valued at USD 5.88 billion in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 8.5% during 2023-2030. The growing desire of millennials to use colourful ornamental aquarium fish as part of an elegant lifestyle is expected to continue to be a major factor in the development of the industry. The main species include Neon tetras, Angels, Gold fish, Danios and Discus while Guppy and Zebra danio contribute to >14% of trade. Emerging innovations in advanced-design aquariums are supporting market expansion as consumers look for room accents. Two other trends that have been around for a while but are still popular are planted tanks and the water feature.

In 2021, freshwater ornamental fish were the world's 3575th most traded product, with a total trade of $307M. Between 2020 and 2021 the exports of freshwater ornamental fish grew by 21.2%, from $253M to $307M. Trade in freshwater ornamental fish represented 0.0014% of total world trade. Recent technological advances in the pet industry, such as pet webcams and automatic filters, have increased the willingness to adopt pets. Modern technology has made it easier than ever to grow and maintain a thriving aquarium at home. For example, monitoring water chemistry in aquariums has been a constant concern for years. That said, new in-tank devices can now measure everything from pH levels the o water hardness in real-time, making it easier to manage ideal conditions.

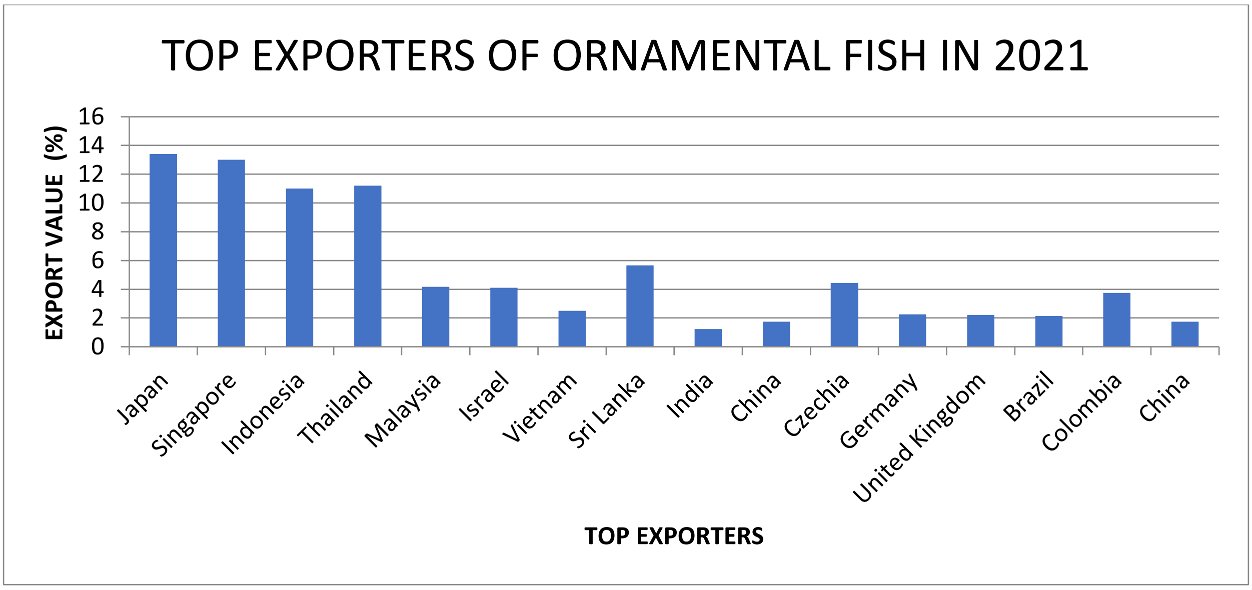
Organizations that rely on natural collection also recognize the need for a sustainable source that protects biodiversity. Consumer demand is growing for animals that are sustainably sourced without harming the ecosystem. Therefore, the rise of the sustainability trend among consumers offers opportunities for market growth. In addition, large ornamental fish producers try to protect aquatic biodiversity not only for financial sustainability but also as a human community that appreciates nature.

Europe dominated the market in 2022 with a share of more than 38.7%. This is due to the massive import of ornamental fish from Asian countries such as Singapore, Thailand and Japan to meet the huge demand for ornamental fish in the region. As fish farming is a simple and stressless hobby, ornamental fish also promote import and export activities and foreign exchange. In addition, European countries such as the Czech Republic, Spain, Israel, Belgium and the Netherlands now breed a variety of ornamental fish, according to the University of Florida's Institute of Food and Agricultural Sciences. In addition, fish production near consumption centres is more profitable due to low transport costs.

Asia Pacific is poised to register the fastest CAGR of around 9.6% during the forecast period. Under the leadership of China, Japan and India, the region has developed into one of the world's most important ornamental fish markets. The increase in demand for high-quality and exotic ornamental fish can be attributed to the expansion of regional markets. The popularity of fish in Japanese artistic culture increased the demand for several unusual species of fish. The popularity of rare exotic fish as a status symbol among Asia's elite offers opportunities for market expansion. For example, the Asian Arowana is one of the most expensive aquatic species in the world, with prices ranging from $300 to $300,000 or more.

Top ornamental fish exporting country

In 2021, the top exporters of ornamental fish are Japan, Singapore, Thailand, Indonesia and Sri Lanka.

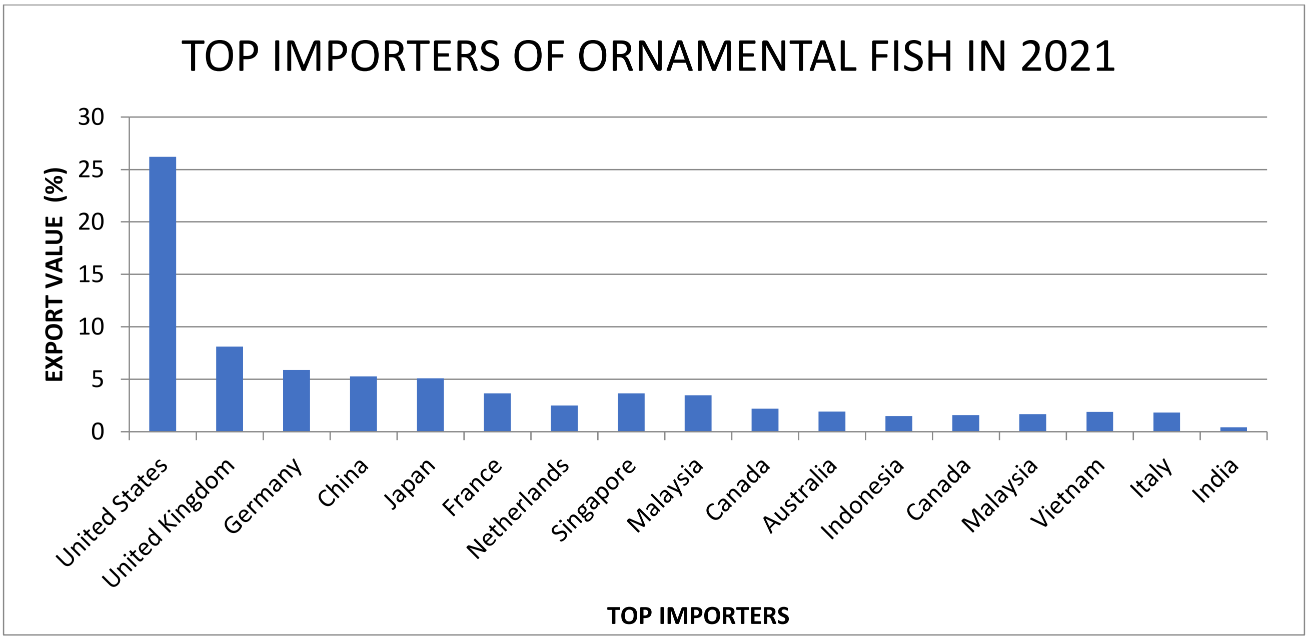


In 2021, the exports of ornamental fish grew the fastest in

- Thailand ($ 8.2 M)
- Japan ($ 7.4 M),
- Singapore ($ 7.06 M),
- Philippines ($6.46 M), and
- Israel ($ 4.73 M)

Top ornamental fish importing country

In 2021, the top importers of Freshwater ornamental fish are the United States, United Kingdom, Germany, China and Japan.



Between 2020-2021 the imports of freshwater ornamental fish grew the fastest in

- United States ($ 19.6 M)
- United Kingdom ($ 7.14 M)

- Malaysia ($ 3.65 M)
- Vietnam ($ 2.99 M), and
- Japan ($ 2.79 M).

The market is characterized by the presence of several well-established and new firms. To compete, businesses in the market are introducing new fish as well as related products, acquisitions, and collaborations. Additionally, measures are being implemented to boost market contribution and use expertise. A contract was made between Qian Hu Corporation Limited and Aqua Easy Pte Ltd. in December 2021 to help prawn farmers follow sustainable aquaculture practices and boost production and profit while minimizing risks and costs. The sensors, software, and services offered by Aqua Easy are combined using data analysis tools.

Imperial Tropicals joined forces with the Japanese fish food company Hikari in November 2021. All varieties of fish, whether farmed or taken in the wild, can use this brand of feed. In order to maintain the health of their fish, this cooperation enabled customers to become familiar with the brand of fish food. In the worldwide ornamental fish market, some significant participants are:

1. Aqua-Nautic Specialist Pte Ltd.
2. AlgaeBarn LLC
3. bioAquatiX
4. Imperial Tropicals
5. LiveAquaria
6. Oasis Fish Farm
7. Sanyo Aquarium (Pte) Ltd.
8. Qian Hu Corporation Limited
9. Sunbeam Aquarium Pte Ltd.
10. Tropical Fish International Pte Ltd.

Status of ornamental fish farming in India (domestic/ national market)

India is one of the largest markets for aquarium items, and during the past ten years, this niche sector has undergone tremendous change. A description of the global market Ornamental fish has recently attracted increasing attention due to the increase in domestic and worldwide demand, as well as the resulting expansion of commerce and the export market. Ornamental fisheries is the 2nd most popular hobby with 100 million hobbyists in the world. India's Exports of ornamental fish have increased in value significantly since 1985, with an average yearly growth rate of around 14%. The value of global exports is made up of emerging countries to about two-thirds. India's share of global ornamental fish export is 0.4% and it is ranked 31st in exporting countries. Due to the favourable atmosphere and wide variety of tropical fish, the industry in the nation has a great deal of potential to expand. The

Department's action plan for the development of ornamental fisheries for the years 2020–2025 focuses on the prospective states for these fisheries based on the resource potential and the current value chain mechanism for fish production and sale. West Bengal, Tamil Nadu, Kerala, Maharashtra, Odisha, Gujarat, Karnataka, Assam, and Manipur have all been named as promising states for the development of ornamental fish. For the advancement of this industry, the department has been working cooperatively with ICAR-CIFA and other universities.

According to the Seafood Export Development Authority of India, there are one million ornamental fish enthusiasts in India. India's exports amount to roughly $0.38 million and its internal commerce is expected to be about $3.26 million. The commerce in ornamental fish is growing by 14% yearly. India is a good location for ornamental fish farming due to its abundance of species, favourable temperature, and inexpensive labour. The three states with the biggest significance for ornamental fish farming are West Bengal, Kerala, and Tamil Nadu. Exotic and native ornamental fish are both marketed from India.

Exotic varieties account for 99% of domestic sales. The top export hubs are Kolkata, Mumbai, and Chennai. About 90% of India's exports come from Kolkata, 8% from Mumbai and 2% from Chennai. About 4,000 people are involved in this business, including processing, live food collection, trade and export. The industry as a whole, including non-exported goods, salaries, retail sales, and related materials has been valued at about $15 billion. There are 20 registered exporters.

The Indian market presently offers 288 unique variants. These freshwater fish, which come in over 200 species, are raised across India. The majority of domestic ornamental fish are exported. Native ornamental fish are abundant in the North Eastern states, West Bengal, Kerala, and Tamil Nadu, and they have great potential. The northeastern states provide 85% of the local fish. 90% of the locally available ornamental species are harvested and grown for export. Currently, some 100 local fish species have been set aside for aquarium use.

Only a few indigenous fish species are now exploited in the ornamental fish trade. Exotic fish are the only ornamental fish sold in India. Even though many native species have a lot of potential as decorative fish, they haven't yet been utilized adequately. Indian waterways are home to more than 100 native freshwater ornamental fish species. Some of these species are traded outside of the country and fetch significant prices on the global market.

Indian ornamental fish resources

With 700 indigenous marine decorative fish species and 374 native freshwater ornamental fish species, India is a nation with a high level of biodiversity. Over 300 marine exotic fish species and 261 egg-laying foreign freshwater fish species are included in the native ornamental fish population. About 80% of the ornamental fish trade's contributions come from freshwater sources, while the remaining 20% come from brackish and marine environments.

Freshwater ornamental fish resource in India

India is fortunate to have a large diversity of freshwater fish, both in the North Eastern hills and the Western Ghats. India's Western Ghats are one of the 34 "hotspot" locations for biodiversity. The Western Ghats are home to 300 species of freshwater fish, 155 of which are considered ornamental fishes and 117 of which are native to these waters.

Barbs, Rasboras, Killifishes, Glass fishes, Catfishes, Hill trouts, and Danios are just a few of the fish species found in the Western Ghats that are good prospects for the ornamental fish trade. About 85% of the market originates from the northern regions, with the remaining 15% coming from the southern states of India. There are 250 different species of ornamental fish in the North Eastern states, 58 of which are currently exported. *Botia dario, Dania dangila, Puntius shalynius, and Schistura reticulofasciatus* are the most promising species from the northeastern states for aquarium fish.

Marine ornamental fish resource in India

The lagoons and coral reefs of the Lakshadweep and Minicoy Islands, the Andaman and Nicobar Islands, the Gulf of Kutch, the Coast of Kerala, the Gulf of Mannar, and Palk Bay are just a few examples of India's abundant marine ornamental fish resources. Acanthuridae, Balistidae, Chaetodontidae, Haemulidae, Labridae, Pomacanthidae, Pomacentridae, Scaridae, and Syngnathidae are just a few of the 24 families that make up the 113 marine ornamental finfish species that have been identified in the Gulf of Mannar. Lakshadweep Islands produce 300 kinds of marine ornamental fish, whereas Andaman and Nicobar Islands add 150 species.

Status of breeding of freshwater ornamental fish

About 13 indigenous freshwater ornamental fish species successfully bred in captivity in which the Kerala queen, *Puntius denisonii* has been used for mass-scale seed production and trading. Rosy barb, *P. conchonius* is being utilized for varietal development and Shining barb variety has been developed

Status of breeding of marine ornamental fish

CMFRI has developed hatchery technology for 14 species of marine ornamental fish species including 5 Clown fish species, 8 damsel fish species, and 1 Dotty back fish.

Ornamental fish trade in Tamil Nadu

Tamil Nadu is a very prolific state whose output should be imitated in several areas, including veterinary, fishery, and agriculture. The state has a distinguished history of raising ornamental fish, and because of its contributions to the domestic and foreign markets, it is regarded as the uncrowned monarch of the ornamental fish industry in India. The state is the major funder of India's domestic ornamental fish marketing industry. Tamil Nadu occupies the second position in ornamental fish export from India. The state's fisheries, the Tamil Nadu Fisheries Development Corporation, the M.S. Swaminathan Foundation, the Marine Products

Export Development Authority, and well-known non-governmental organisations like Dhan and the Fisheries Universities have all made significant contributions to the growth of the state's artisanal fisheries.

According to export data from April 2020 to March 2023 the major exporters of Tamil Nadu the major exporters are,

1. M/s Aqua World Exports (P) Ltd (Unit Value 4. 8 Lakh)
2. Blue Planet Aqua (Unit Value 7.77 Lakh)
3. SAH Enterprises (Unit Value 3.08 Lakh)
4. Blue Planet Aqua (Unit Value 1.91 Lakh)

In Tamil Nadu, a high percentage of the breeding units were located in Thiruvallur (Kulathur), followed by Dindigul and Madurai districts. It is noted that among the five states surveyed Tamil Nādu topped in Ornamental fish production. The state has more potential for enhancing production but faced many constraints. Financial institutions never saw ornamental fisheries as a successful industry and instead saw it as a dangerous one. The breeders were forced to sell to only those wholesalers from whom they had received money after the traders noticed that the breeders were having this problem. A significant restriction for the breeders was the high electricity charge.

To overcome the constraints faced by ornamental fish breeders of Tamil Nadu the government will build a trade centre for ornamental fishes to facilitate exports and increase production in public-private-partnership (PPP) mode at an outlay of Rs 50 crore. The centre, would meet international standards as stated by the Fisheries Minister of the state Mr. Radhakrishnan. He added that about 2,000 families are involved in farming and sale of ornamental fish in the Kolathur area here and the centre will benefit them.

Ornamental Fish Production System based in Kolathur, Chennai

Nearly 1,850 ornamental fish production operations operate in Kolathur and the adjoining areas of Athur and Devanpumedu, supplying ornamental fish to the Kolathur-based wholesale market. The region's ornamental fish production system primarily involves a hatchery engaged in the production of fried ornamental fish. There are small farms that specialize in rearing small tanks and glassware, and large ornamental fish farms that raise large numbers of fish.

Ornamental fish hatchery units

Most of the ornamental fish farms are located in New Lakshmipuram and Vinayagapuram villages in Koratur, Chennai. This unit mainly houses fish species such as goldfish, guppies, and angels. Each hatchery has an average site size of 20 cents and approximately 16-20 12 x 5 feet tanks. Some tanks are used only to prepare the breeding environment, while others are used for release. Nearly all of these units use self-grown Artemia as bait for French fries. Fish fries are sold for 10-30 paisa each.

Small-scale grow-out units

Smaller growing units source fish fries from nearby hatcheries and store them for about two months before selling them to wholesalers. The area of the production unit is about 20-30 cents, and great care is taken in the cultivation. Procured fish fries are stored in cement tanks fitted with water filtration and aeration facilities. Each unit tanks approximately 25,000 to 30,000 fry per cycle, depending on the species being reared. Many of these sectors are family owned and operated, with women making up the majority of the workforce. For fries are fed twice a day (early morning and evening) with locally available red worms. Blood worms (larvae of the genus Chironomid) are a high-protein forage that is netted from local water bodies. They are said to be an excellent food source that supports the rapid growth and attractive colour development of juvenile ornamental fish species. Red worms are sold in small packs for €50 . Once the fish are large enough to sell, they are taken to the Kolasar Wholesale Market where they fetch an average price of $5-10 per fish.

Large-scale ornamental fish farms

The majority of the large-scale ornamental fish farms are located in Athur village, which is near the Chennai-Hyderabad highway and roughly 9 kilometres from Red Hills in Chennai. A group of farmers and businesspeople who realised the lucrative potential of the ornamental fish industry turned about 100 acres of paddy cultivation area into substantial decorative fish farms.

The primary supply of water for farming in this area comes from borewells. Here, popular ornamental fish species like Tetra, Angel, Shubunkin goldfish (SK), and goldfish are cultivated on a huge scale. A pond in Athur typically measures approximately 6 feet deep and 30 cents. Currently, roughly 300 of these ponds are used for decorative aquaculture, and depending on the species, each one may hold anywhere between 10,000 and 30,000 ornamental fish during a culture cycle.

PROBLEMS AND FUTURE PROSPECTS

In India, several technical and economic challenges affect the ornamental fish sector. The primary barriers to progress are a lack of specialised knowledge, scientific understanding of breeding, types of feed, and health management. Most company owners are unaware that this newly developing area or industry has a far higher profit margin than prawns while needing much less capital and risk. India hasn't been able to transport marine ornamental fish very far because of a lack of infrastructure. Because of ignorance, most of India's native ornamental fish are inexpensive and are eaten as food in rural areas and small towns. The commerce in Indian ornamental fish is chaotic in many ways. Only freshwater fish species, mostly from the North-Eastern parts of India, are being exported from that country as ornamental fish. Our nation has an abundance of natural water bodies and a diverse range of species, which has the potential to greatly increase export revenues to more than $20 million US yearly. Aquatic plants that may be used as decorations are also present in our bodies of water. In addition to natural collecting, growing these plants is a possibility to meet the need of the ornamental fish market. Aquariums and their accessories have great development potential for businesses with minimum start-up costs.

CONCLUSION

At a never-before-seen rate, both freshwater and marine ornamental fish demand is rising. The majority of marine ornamental fish bought on the market are taken from their native habitats. To meet the rising demand in the export market, it is necessary to improve marine ornamental hatchery technology and to produce young ones. Although the country has scientifically advanced the breeding methods for a few indigenous ornamental fish, their large-scale production has not yet started. More indigenous ornamental fish can be generated for increasing exports from the country if government institutions can build up large-scale facilities and offer specialist training and help breeders.

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ADVANCED FARMING SYSTEMS IN AQUACULTURE- STRATEGIES TO ENHANCE THE PRODUCTION

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Introduction

The world's appetite for fish is steadily growing. Finfish and shellfish currently make up one-sixth of the animal protein people consume globally. As the global wild fish catch peaked in the 1990s, aquaculture—or fish farming—has grown rapidly to meet world fish demand, more than doubling production between 2000 and 2012. New research shows that aquaculture production will need to more than double again between now and 2050 to meet the demands of a growing population. WRI partnered with World Fish, the World Bank, INRA, and Kasetsart University to explore this question. Our new paper, Improving Productivity and Environmental Performance of Aquaculture, examines aquaculture's environmental footprint today and explores various scenarios of aquaculture growth to 2050. It uncovers several strategies that can lessen aquaculture's environmental impacts while also ensuring that fish farming provides employment and nutritious food to millions more people. The aquaculture industry has greatly improved performance over the past 20 years, producing more farmed fish per unit of land and water, lowering the share of fishmeal and fish oil in many aquaculture feeds, and largely stopping mangrove conversion.

However, doubling aquaculture production without further increasing the industry's efficiency could lead to a doubling of environmental impacts. And unless the aquaculture industry is able to boost productivity, the limited availability of land, water, and feed may constrain its growth. Advanced aquaculture practises includes,

- Cluster Farming
- PAS
- System 80:20
- BFT
- Cage
- RAS

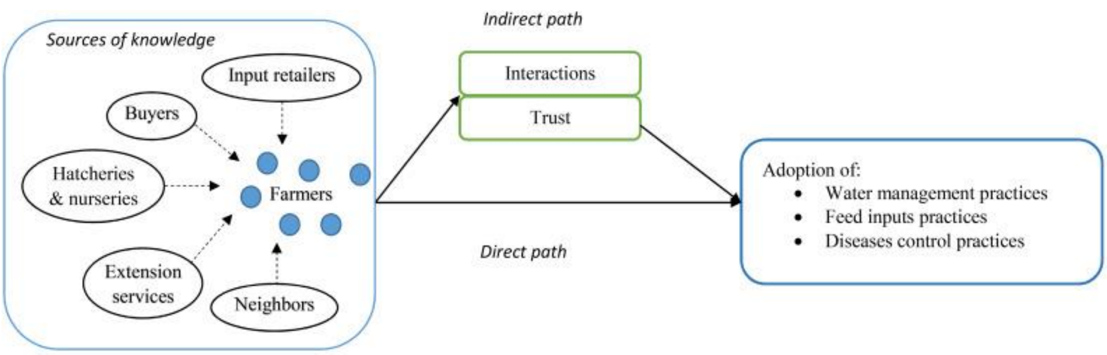
1. Cluster Farming

Cluster is a group of farmers whose shrimp ponds are situated in a specified geographical locality; commonly all ponds are dependent on the same water source.

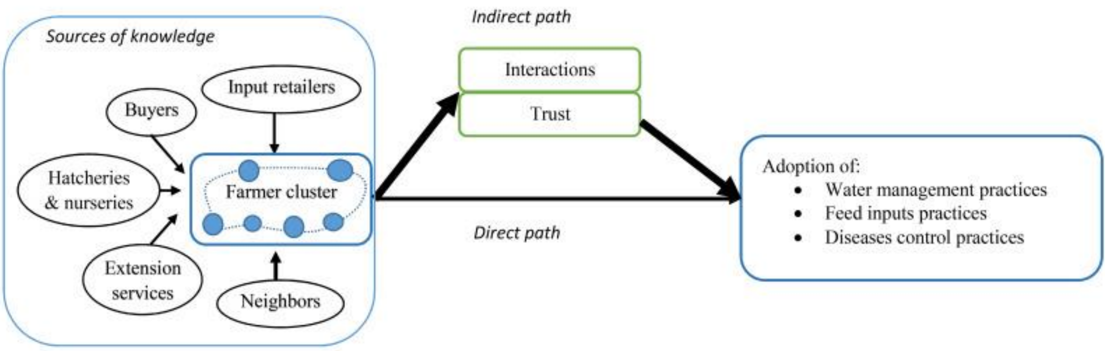
Cluster farming having the following salient features:

- Each Cluster contains 20 to 50 Farmers
- Small scale farmers
- Use common water supply channel.
- All farmers are registered under Costal Aquaculture Authority

- Also got cluster certification from MPEDA
- The cluster farmers should elect their own governing board
- 7 members such as President, Secretary, Treasurer and committee members
- The Cluster society should prepare their rules and regulations (Bylaw)
- Registration number from state govt.
- Should not use any banned chemicals and Antibiotics
- Cluster people should maintain all records and documents for the traceability
- Society accounts are audited by MPEDA



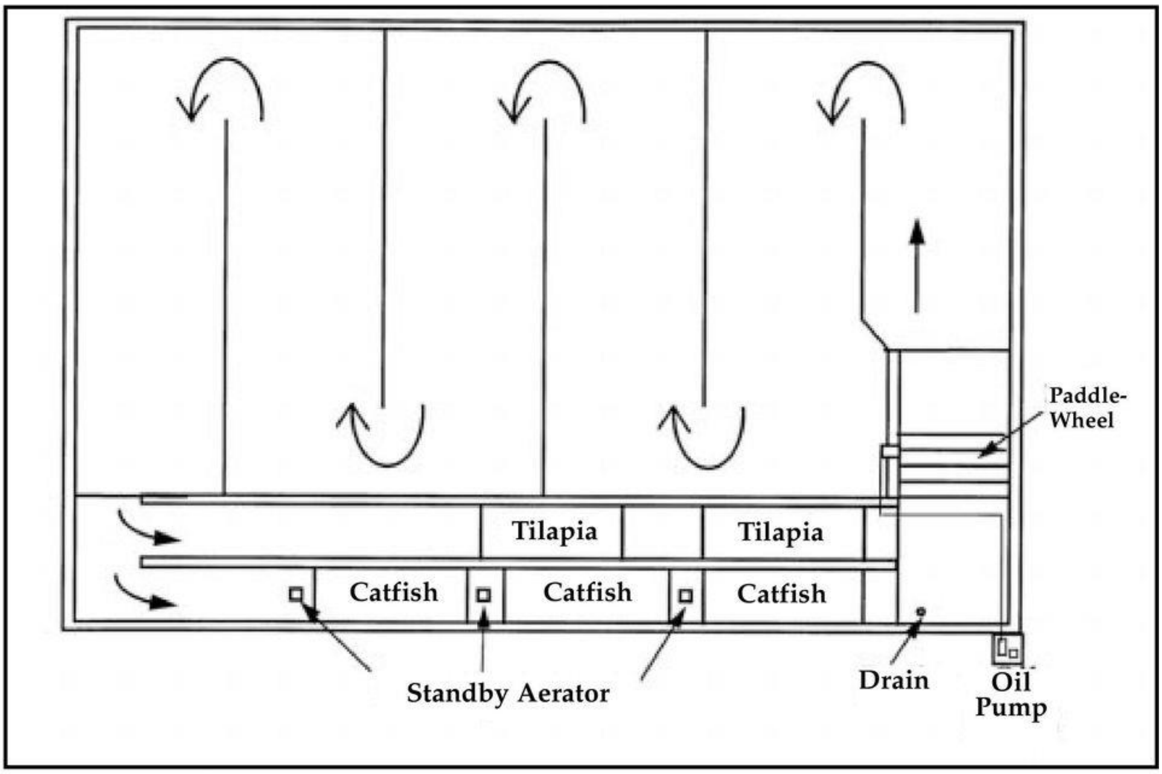
a) *Non-cluster farmers model*, where interactions between the sources of knowledge and farmers are depicted by (-------►) and between individual farmers are infrequent and trust is relatively low which leads to limited adoption of technologies and practices. The indirect path to adoption is limited in magnitude (⟶)



b) *Farmer cluster model* where interactions between the sources of knowledge and farmers (⟶) and between farmers are relatively frequent and trust is relatively high, which leads to adoption of technologies and practices. The indirect path to adoption is relatively stronger in magnitude (➡)

2. Partitioned Aquaculture Systems (PAS)

The main principle of PAS is water from raceways is flow into the algal culture channels. The flow water is maintained by aerator in algal unit the waste from water is removed and it is used as nutrient for their growth. Then the purified water is again circulated into the raceway unit. The component of PAS are fish raceway unit, paddle wheel aerator and algal channel.



Advantages

- Fish waste can be recycled
- Increased carrying capacity of fish by high primary production and o2 by algae
- It can increased yield 4-5 times
- Release of nutrient rich water to the environment is reduced.
- Yield the high value fish and algal species .
- Additional aeration is not required
- Use of fertilizers is reduced
- Low input of water

3. System 80:20

The 80:20 system provides higher yields and higher profit than monoculture. It is promoted in India, Indonesia and Philippines by American Soybean Association International Marketing and China's extension service. The 80:20 pond fish culture system combines intensive production of one high-value species such as catfishes, tilapia with a "service species" such as the filter feeding silver carp which helps to clean the water and the carnivorous mandarin fish (*Siniperca chuatsi*) which controls wild fish and other competitors. Eighty percent of the harvest weight comes from the pellet-fed target species and the other 20 percent comes from the filter feeding service species. Such systems are widely thought to be more environmentally sustainable, however, economic incentives are driving intensification and specialization, resulting in changes to such traditional systems, with likely loss of environmental services.

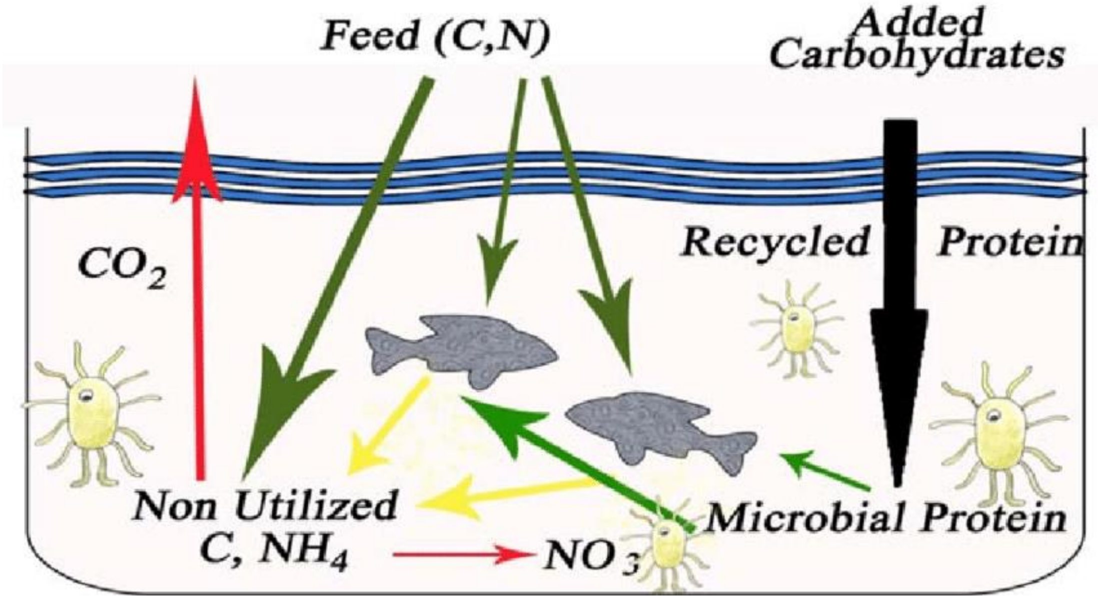
4. Bio-Floc Technology

In BFT, a co-culture of heterotrophic bacteria and algae is grown in flocs under controlled conditions within the culture tank / pond. Microbial biomass is grown on fish excreta resulting in removal of unwanted components from the water. In this technology the major driving force is the intensive growth of heterotrophic bacteria that will consume organic carbon. For instance, 1.0g of carbohydrate-C yields about 0.4g of bacterial cell dry weight-C; and depending on the bacterial C/N-ratio they immobilize mineral nitrogen.

Biofloc technology (BFT) systems were originally developed to minimize effluent discharge, protect the surrounding water resources and improve farm biosecurity. When water exchange is limited, organic matter in the water is built up. Organic matter is the substrate needed for the development of a heterotrophic microbial community, microbes that get their energy by metabolizing organic molecules. Intensification, aeration, mixing and limited water exchange, all led to the development of microbial dominance in the tank. Bioflocs are different in different systems. More algae are included in the flocs of open and less intensive ponds, as compared to very intensive covered ponds. The age of the biofloc may be of importance, as older ones are expected to contain higher proportions of grazers than the most preferred heterotrophic bacteria.

Biofloc system:

The basis of BFT systems is the bioflocs. The bioflocs are conglomerates of microbes, macroaggregates composed of diatoms, macroalgae, protozoa, fecal pellets, exoskeleton, and remains of dead organisms, dead organic particles, bacteria and invertebrates. Bioflocs found in ponds are porous, light and have a diameter of 0.1 to a few mm. The basic requirements for biofloc system operation include high stocking density with 3 to 5 kg of fish or 130-150 PL10/m^2 and high aeration either through the blower or with correct paddlewheel position in ponds. Ponds must be invariably lined with concrete or high density polyethylene (HDPE), while the tanks do not require any special wall for this. Pellet grain and molasses are added to the culture water. Fish production can be enhanced up to 5 times than the normal production and shrimp production of 20-25 mt/ha/crop is normal for biofloc systems. A maximum production of nearly 50 mt/ha was achieved in small ponds in Indonesia.



Floc formation

There are several binding mechanisms that affect floc formation, shape and stability. Many organisms are coated by extra-cellular polymers made of polysaccharides, proteins, humic compounds etc. These slimy polymers act as glue, embedding cells and other particles together. Filamentous organisms help in bridging between the different floc forming components. Due to exploitation by the fish and also other organisms, microbial degradation may happen which can be immediately rectified by the fast developing nature of the bacteria. The biota in the flocs change 2-3 times a day and is mostly made out of young and active cells.

Bioflocs in feed and feeding:

Analysis of minerals indicates that microbial flocs are rich in phosphorus and a wide range of other minerals. Much of these minerals may be bound to bacteria in a bio-available organic form. Bioflocs contain different growth and probiotic factors. It can replace the vitamins typically supplied in any intensive farming systems and in the feeds for fishes. Feeding the fishes like tilapia with bioflocs raise specific activity of enymes by about two fold, possibly contributing to growth enhancement. Uptake of the bio-flocs by fish depends most probably on the fish species and feeding style, fish size, floc size and floc density.

Bioflocs in disease management:

The heterotrophic microbial biomass is suspected to have a controlling effect on pathogenic bacteria that are normally present in any aquaculture system. All intensive farming systems are heavily loaded with organic matter principally of fish biomass and therefore the chances for the outbreak of diseases are comparatively more. But the presence of biofloc can help in the control of disease outbreak also. Short chain fatty acids as bio-control agents against pathogenic diseases are of particular interest in bioflocs. Emphasis can be put on the organic storage product such as poly-β-hydroxybutyrate (PHB). This is an intracellular biodegradable polymer produced by a wide variety of micro-organisms and is involved in bacterial carbon and energy storage. This polymer can depolymerize in the fish gut and release butyric acid, a known anti microbial agent. As such, PHB might offer a prebiotic advantage for aquaculture.

Moreover, these compounds are capable of exhibiting bacteriostatic and/or bacteriocidal properties, depending on the physiological status of the host and the physiochemical characteristics of the external environment (Ricke, 2003).These indicate that biofloc can be a novel strategy for disease management on a long-term basis, in contrast to conventional approaches such as antibiotic, probiotic and prebiotic application. There are no reports of direct use of biofloc (PHA or SCFA) as antimicrobial neutraceuticals in fish feed, many projects are focusing on the characterization and optimization of PHA production by these flocs and analysing their bio-control efficacy in different host-microbe systems

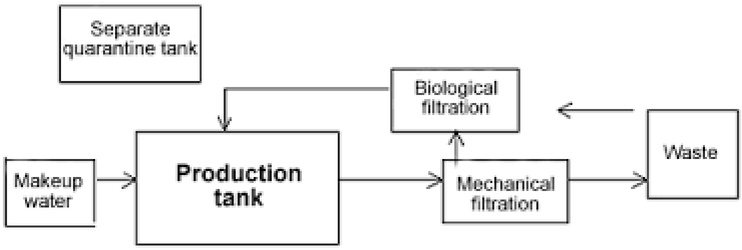
Biofloc and water quality management:

Nitrogen control is very strongly stimulated by feeding bacteria with carbohydrates and through the subsequent uptake of nitrogen from the water by the synthesis of microbial protein. The relationship between adding carbohydrates, reducing ammonium and producing microbial proteins depends on the microbial conversion coefficient; the C/N ratio in the microbial biomass and the carbon contents of the added material. The C/N ratio has been widely used as an index of the rate at which organic matter decomposes. If the organic matter present in the tank contains less nitrogen content (i.e. a high C/N ratio), some of the nitrogen for microbial growth will be obtained from the water column and will become immobilised as microbial protein.

If carbon and nitrogen are well balanced in the medium, ammonium in addition to organic nitrogenous waste will be converted into bacterial biomass. By adding carbohydrates to the pond, bacterial growth is stimulated and nitrogen uptake through the production of microbial proteins takes place. This promotes nitrogen uptake by bacterial growth decreases the ammonium concentration more rapidly than nitrification. Immobilization of ammonium by heterotrophic bacteria occurs much more rapidly because the growth rate and microbial biomass yield per unit substrate of heterotrophs are a factor 10 higher than that of nitrifying bacteria. These factors help in the water quality management in the intensive farming systems.

5. Recirculatory Aquaculture systems

Recirculatory system are usually characterized by minimal connection with the ambient environment and the original water source. These system have minimal exchange of water during a production cycle. Some water is discharged and replaced each day in most recirculating tank system. Regular maintenance of accumulated solids and water quality is maintained by pumping the culture water through filtration and aeration.



The increased focus on RAS for fish production is due to:

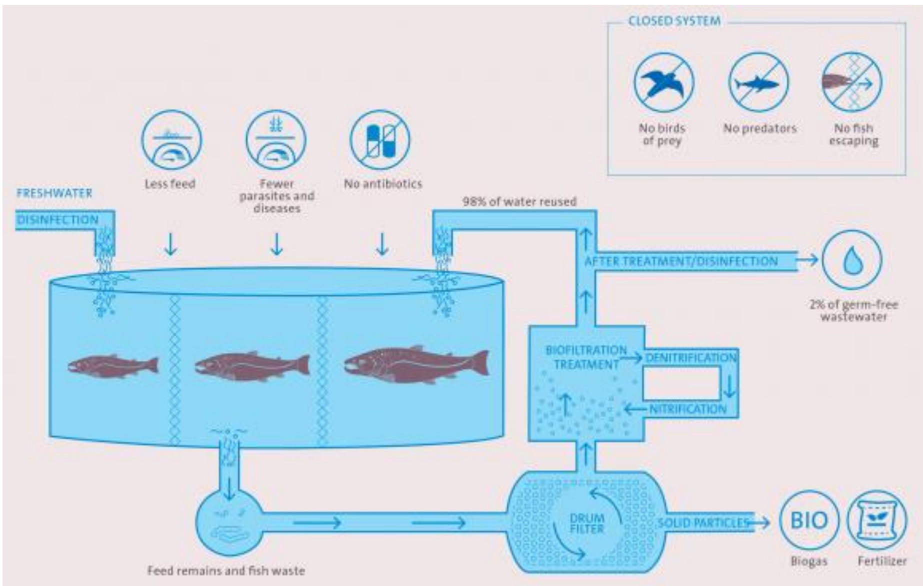
(i) limitations in freshwater resources especially during dry periods of the growing season.

(ii) problems associated to inlet water quality as most water bodies have relatively soft water (low calcium) requiring liming or silicate to increase alkalinity.

(iii) need for UV irradiation/ozone treatment for disinfection purposes;

(iv) need for stripping off high levels of CO_2(ground water).

(v) the advantages of constant, optimized temperature conditions offered in RAS in contrast to open systems.



6. Aquapod

It is a circular structure formed by joining triangular net parts. It is suitable for aquaculture in open sea conditions due to its sinkable structure and it is completely surrounded by nets. When air in the system is filled and emptied, the position of the water column and water level are adjusted. Feed is given by float pipes which communicate with the water surface. Divers and electronic devices keep the system under constant control.

7. Smart Floating Farms

This system consists of many layers and it is a highly productive system. Top floor of the system has solar panels to meet the energy need of the system, middle layer has area for vegetable production and bottom layer has pools for fish production. With the aquaponic production, the wastewater from the fish ponds is used in vegetable production, while the vegetable products can be used in feeding fish. The system, including the energy field, is capable of self-sustaining and highly sustainable production. The packaging units located in the middle section helps to ship the harvested products directly. This system is especially good for cities with a high population.

8. Ocean Farms

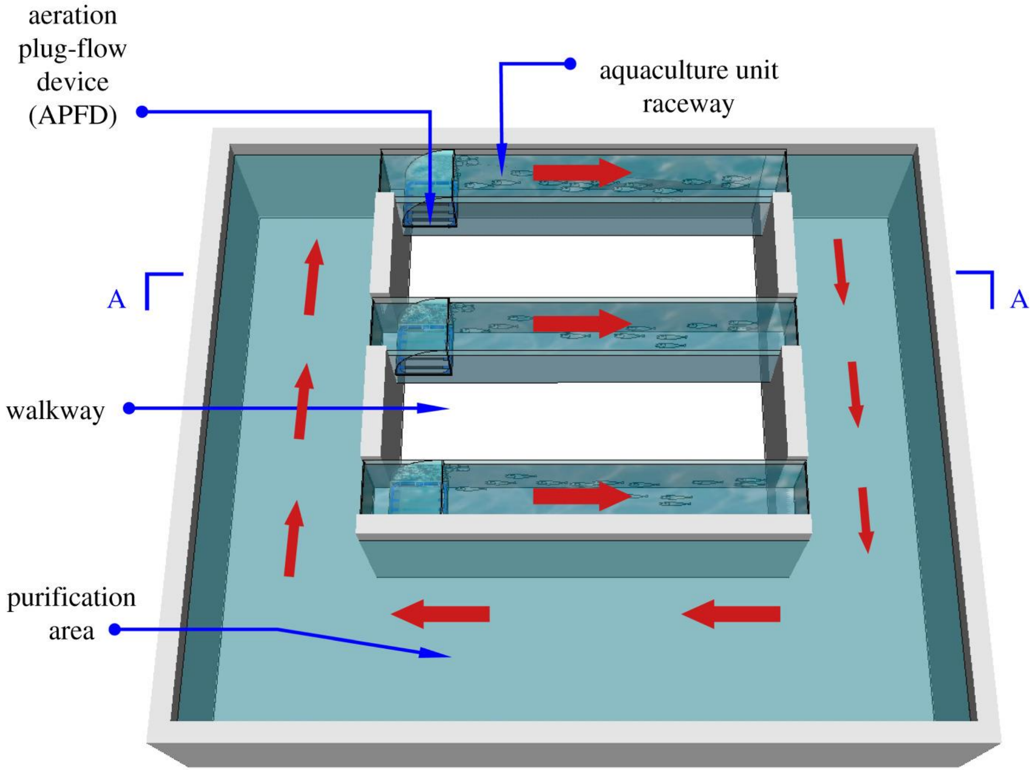
The system is made of steel with a diameter of 110 meters and a depth of 42 meters. The presence of the control room and feed reservoir in the system minimizes the logistic need from the shore, and every stage of production can be controlled and intervened if necessary. With this farms, 8 times more production can be realized than the standard net pen systems.

9. NordlaksHavfarm

The system looks like a big ship. It has 6 net pen cages with dimensions 50mx50mx60m. When fully operational, 10,000 tons of production can be done. The system is fixed to the floor by the head and its position changes towards the wave direction with the help of the propellers on the rear side. The desired time allows for displacement. All operations such as feeding, moving fish and harvesting are carried out in the system using mechanization.

10. In-pond raceways (IPR)

It is a cage like system that could be adapted to almost any water body but with the advantage of controlled water movement to improve the water quality and allow for increased stocking density. The IPR system is more environmentally sustainable than cages, raceways and intensive open-pond production systems. However, research on cost-effective solid and liquid waste reduction methods need to be evaluated and further developed.



ADVANCING TOWARDS INTEGRATED AQUACULTURE PRACTICES

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The concept of integrated aquaculture is mainly focusing on the resource sharing and revenue enhancement to the farmer. This can also be termed as "efficient resource utilization" and regular revenue yielding for the farmer in order to sustain his expanded farm activities and other domestic business. In such type of integration, aquaculture may either be a secondary or tertiary activity, and rarely assumes primary status. Nevertheless, there are places where the revenue that can be obtained from fishes harvested is more attractive than that of from other farming activities and in such places aquaculture can be done as a primary activity in the integrated farming. Some of the integrated aquaculture practises includes,

- Polyculture
- Integrated farming
- Aquaponics
- Integrated Multi-trophic Aquaculture

1. Polyculture

Polyculture in aquaculture is the association of fish species of different food habits for the effective use of available fish foods in the pond, where wastes produced by one species may be inputs for other species. Polyculture is the main fish culture system in Asia, the continent generating over 90% of the world aquaculture production. There are research pertaining to the combination of intensive aquaculture system with the extensive polyculture system. This is due to the maximization of the organic matter in the discharge water of the intensive culture unit. This polyculture unit will thrive on the organic matter of the intensive unit there by acting as a biofilter for the organic matter rich discharge water making the water free from the organic matter.

Advantages

- Reduce the environmental impacts
- Gives sustainable production.
- More sustainable and profitable system.
- No need for supplement feed.
- Biologically well-balanced system.
- Production of different species in one culture

2. Integrated farming

In many farms located in the agriculture dominated countries, the farmers are aware of the benefits of keeping a small pond like structure of minimum 100 sq.m area to store the water and use it for agriculture or horticulture crops in their field. Some farmers even prepare this small pond for fish production. Most of the farms although small, may have a unit of dairy with two or three cattle, few birds and ducks together with one or two pigs. It would be a common sight in many farms that the primary focus is only on agriculture. Either food crop or cash crop will be given the primary status in the farming and all the other farming enterprises are either secondary or tertiary based on the level of income that can be taken from them. But in integrated aqua farming, all the units including crop raising have been considered secondary and the aquaculture is given primary status because of the income it can give to the farmers.

Advantages of integration

In an organized aquafarm, where number of ponds will be more than four, the crop raising with banana or cassava or sorghum or any other vegetable along with animal components like cattle, rabbits, pigs and birds remain as ancillary units providing the needed inputs for the aquaculture ponds. After the harvest, the pond bottom can be used for crop raising. Alternatively the pond silt is being used to fertilize the crops and thereby the aquaculture ponds will become the major source of nutrients and effective cultivable area for the crops.

The integrated aquafarms offer great scope for effective resource utilization. In any kind of farming the basic principle is to make use of the maximum possible area for the production and revenue. In an aquafarm this can be achieved by using the bundh area, both inner and outer for various purposes like fodder cultivation, banana cropping, vegetable cultivation, erecting the shed for birds or ducks or livestock, etc. This will help in the utilization of land resource. Similarly water can be used among all the enterprises more effectively as the fertilized water in the ponds when drained can be used for the crops. The bathing water from the cattle shed can be used for fertilizing the ponds. The manpower utilization is full in an integrated farm as the same number of labors can be utilized for all the farming activities. Above all, the wastes generated in one activity can be effectively used in another activity thereby the drain of nutrients can be totally avoided.

Choice of fishes for integrated aquaculture

All types of fish farming can be tried under integrated farming and therefore all fishes are suitable for integrated farming. However, considering the manure input and organic matter accumulation, it has been found that common carp, tilapia and omnivore fishes are much preferred for stocking in the integrated ponds. The reason being the effective utilization of primary production and detritus in the ecosystem.

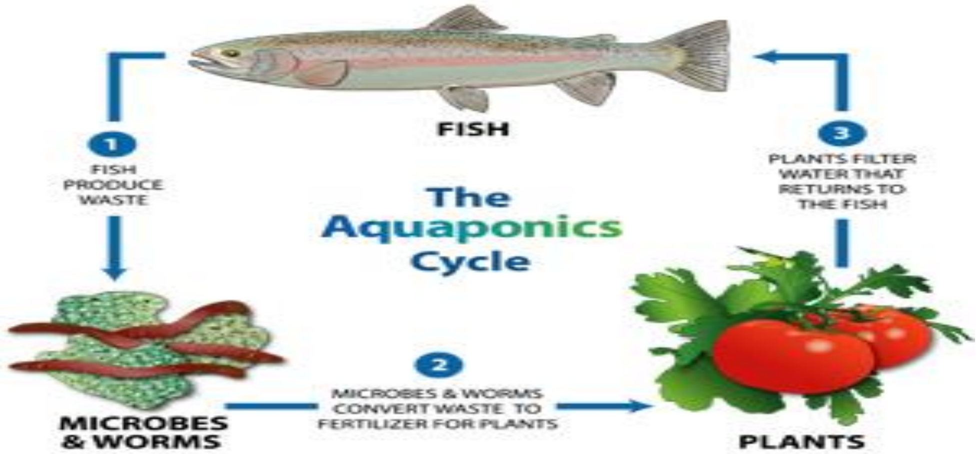
The integrated aquafarming is an enterprise that can be followed for the revenue enhancement and constant income from the farm.

3. Aquaponics

Aquaponics can be defined as the symbiotic cultivation of plants and aquatic animals in a balanced recirculating environment. In this system, the fish provides nitrogenous waste, which serves as a nutrient for the plants, and the plants remove the nitrogenous compounds providing clean water for the fish.

Principles of aquaponics

Aquaponics is the integration of recirculating aquaculture and hydroponics in one production system. In an aquaponic unit, water from the fish tank passes through filters, plant grow beds and then back to the fish. In the filters, the fish wastes are removed from the water using a mechanical filter that removes the solid waste and then through a biofilter that processes the dissolved wastes. The biofilter provides a platform for bacteria to convert ammonia, which is toxic for fish, into nitrate, a more accessible nutrient for plants. This process is called nitrification. As the water travels through plant grow beds, the plants uptake these nutrients, and finally the water returns to the fish tank purified. This process allows the fish, plants, and bacteria to thrive symbiotically and to work together to create a healthy growing environment for each other.



Aquaponic Systems

a. Media Filled Systems

The hydroponic component is first distinguished by whether it employs a media or not. This becomes very important in aquaponic systems because the presence of a media that plant roots are grown in can possibly eliminate the need for a separate settling tank and biofilter. Sludge and solid from the fish tank get caught in the media and are processed by bacterial communities that develop in the media, thereby acting as a biofilter and eliminating the need to remove the solids in a separate system. If the system does not employ a media and plant roots are exposed directly to the water, then a settling tank and biofilter are necessary to return the water quality to sufficient levels in which fish can live.

b. Flood and Drain

In flood and drain systems, plant roots are exposed to a static nutrient solution for hours at a time before the solution is drained away, which could happen several times a day. The technique can be used regardless of whether a media is used in the system, and plant roots could either be completely submerged, or partially submerged, leaving a portion exposed to the atmosphere. Flood and drain systems are noted for their simplicity, reliability and user-friendliness.

c. Nutrient Film Technique (NFT)

Nutrient film technique consists of the plant roots being exposed to a thin layer of nutrient water that runs through a PVC pipe. In this method, the shallow flow of water reaches the bottom of the thick layer of roots that develops in the trough while the top of the root mass is exposed to the air, thereby receiving an adequate oxygen supply. NFT can sustain very high plant densities. In aquaponic NFT systems, the biofilter becomes crucial as there is no large surface area whereby bacteria communities can develop.

d. Floating Raft System

Another system that has great potential for commercial use is the floating raft system. In this system plants are grown on floating Styrofoam rafts. The rafts have small holes cut in them where plants are placed into net pots. The roots hang free in the water where nutrient uptake occurs. A major difference between the raft systems and the NFT and media based systems is the amount of water used. The water level beneath the rafts is anywhere from 10 to 20 inches deep and as a result the volume of water is approximately four times greater than other systems. This higher volume of water results in lower nutrient concentrations and as a result higher feeding ratios are used. Bacteria form on the bottom surface of the rafts but generally, a separate biofilter is needed. Also, the plant roots are exposed to some harmful organisms that reside in the water, which can affect plant growth.

FISH SELECTION

Several fish species have recorded excellent growth rates in aquaponic units. Fish species suitable for aquaponic farming include: tilapia, common carp, silver carp, grass carp, barramundi, jade perch, catfish, trout, salmon, Murray cod, and largemouth bass, goldfish, Red swamp crayfish and Giant freshwater prawn.

PLANT SELECTION

More than 150 different vegetables, herbs, flowers and small trees have been grown successfully in aquaponic systems. In general, leafy green plants do extremely well in aquaponics along with some of the most popular fruiting vegetables, including tomatoes, cucumbers and peppers. Fruiting vegetables have higher nutrient demands and are more appropriate for established systems with adequate fish stocks. However, some root crops and some sensitive plants do not grow well in aquaponics. Root crops require special attention, and they can only be grown successfully in deep media beds.

Low-nutrient-demand plants include the leafy greens and herbs, such as lettuce, chard, salad rocket, basil, mint, barsley, coriander, chives, pak choi and watercress. Many of the legumes such as peas and beans also have low-nutrient demands. Plants with high-nutrient demand include tomatoes, eggplants, cucumbers, zucchini, strawberries and peppers. Other plants with medium nutrient demands are cabbages, such as kale, cauliflower, broccoli and kohlrab. Bulbing plants such as beets, taro, onions and carrots have medium to high requirements, while radish requires less nutrients.

In media bed units, it is common practice to grow a polyculture of leafy greens, herbs and fruiting vegetables at the same time. Provided media bed units are the right depth (at least 30 cm), it is possible to grow all the vegetables mentioned in the categories above. Polyculture on small surfaces can also take advantage of companion planting and better space management, because shade-tolerant species can grow underneath taller plants. Large bulb and/or root crops, such as kohlrabi, carrots and turnips can also be cultured in media beds

Monoculture practices are more prevalent in commercial NFT and raft units because the grower is restricted by the number of holes in the pipes and rafts in which to plant vegetables. Using NFT units, it might be possible to grow the larger fruiting vegetables, such as tomatoes, but these plants need to have access to copious amounts of water to secure sufficient supply of nutrients and to avoid water stress. Fruiting plants need to be planted in larger grow pipes, ideally with flat bottoms, and be positioned over a larger distance than leafy vegetables. This is because fruiting plants grow larger and need more light to ripen their fruits and also because there is limited root space in the pipes.

It is best to start a new aquaponic system with fast-growing robust plants with a low nutrient demand. Some examples are leafy green vegetables, such as salads, or nitrogen fixing plants, such as beans or peas. After 2–3months, the system is ready for larger fruiting vegetables that demand a greater amount of nutrients.

Nutritional Requirements of plants

Plants have different nutritional requirements; for instance leafy green vegetable require more nitrates than fruiting plants. However all plants in aquaponic systems need 16 essential nutrients for maximum growth. The macronutrients needed for the growth includes nitrogen (N), potassium (K), calcium (Ca), magnesium (Mg), phosphorous (P) and sulphur (S) and the micronutrients include chlorine (Cl), iron (Fe), magnesium (Mn), boron (B), zinc (Zn), copper (Cu), and molybdenum (Mo).

Items	Fish feed rates (g/ m^2/ day)	Plant density (plants/ $m^{2)}$	Fish density	Fish feeding rate
Leafy green vegetables	40–50	20–25	10–20 kg / 1000 litres of water	1–2% of body weight
Fruiting vegetables	50–80	4–8		

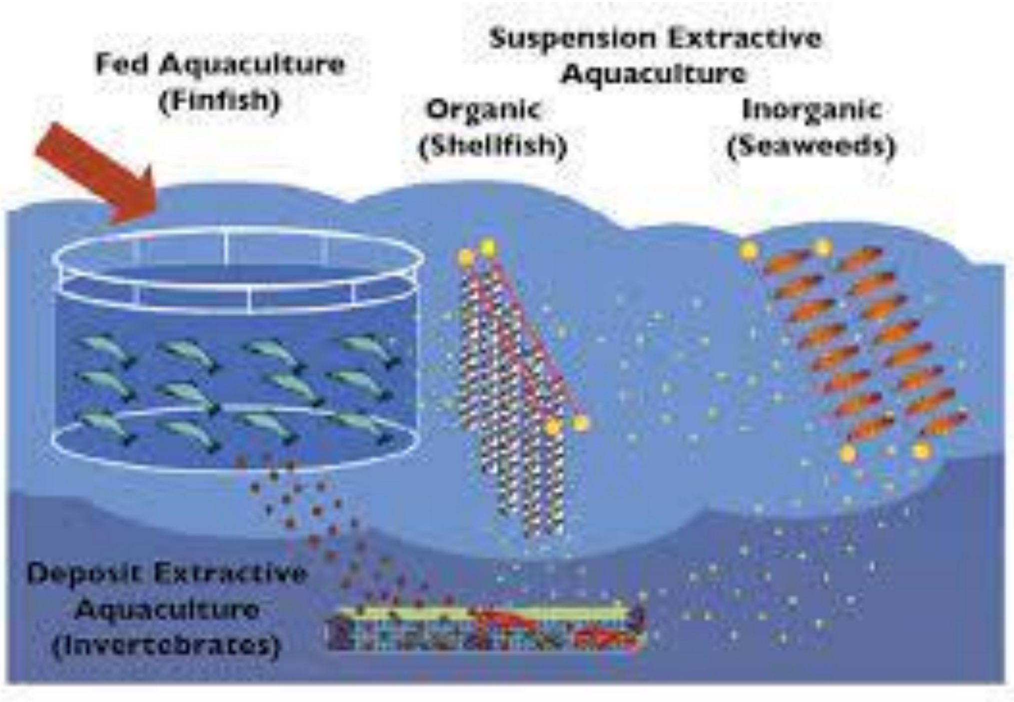
Aquaponic system can address the issues of resource conservation and access to a reliable and quality food source. These systems can be established in the backyard also creating revenue to the families. If taken up, it can give a good production of fish and vegetables leading to sustainable development of the system thus meeting food security needs.

Advantages

- Significant reduction in the usage of water (compared to traditional soil methods of growing plants) as all water is recycled through the system and it is not necessary to discard or change any water (under normal conditions).
- Growth of plants is significantly faster than traditional methods using soil.
- Aquaponics-grown vegetables are bigger and healthier then when grown in soil.
- There is no need to use artificial fertilizer to feed the plants.
- There is no need to dispose of fish waste or provide an artificial filtration system.
- Significant reduction in land is required to grow the same crops as traditional soil methods.

4. Integrated Multi-Tropic Aquaculture (IMTA)

Integrated multi-trophic aquaculture provides the by-products including waste from an aquatic species as inputs (fertilizers, food) for another. Different species is cultured in the same pond to maintain the water quality. The wastes from fish are utilized by shellfishes and they convert organic into inorganic nutrients. These inorganic nutrients are used by seaweed for photosynthesis. The main aim of this system is to achieve environmental sustainability by using the waste of one animal as a fertilizer or feed for other animals.



Selection of species

Fed organisms, such as carnivorous fish and shrimp are nourished by feed, comprising of pellets or trash fish. Extractive organisms, extract their nourishment from the environment. The two economically important cultured groups that fall into this category are bivalves and seaweed. Combinations of co-cultured species will have to be carefully selected according to a number of conditions and criteria:

- Complementary roles with other species in the system
- Adaptability in relation to the habitat
- Culture technologies and site environmental conditions
- Ability to provide both efficient and continuous bio-mitigation
- Market demand for the species and pricing as raw material or for their derived products
- Commercialization potential
- Contribution to improved environmental performance
- Compatibility with a variety of social and political issues

Fed-aquaculture species sub-system in IMTA

In IMTA, fed component is represented by finfishes. These fishes provide dissolved and particulate nutrients and oxidation reduction potential reducing compounds to the other component organisms as well as revenue to the industry. The quantity and form of these nutrients is dependent on species, size and feed formulation among other factors. Feed formulation provides perhaps the most obvious route for fish effluent modification for the extractive components. There is a distinction between IMTA systems that are open (cage based) and semi-closed (recirculation aquaculture systems) to the environment. In most open systems, the environment is both necessary and sufficient to rear extractive organisms, while the semi-closed systems require much tighter coupling of the different trophic levels under cultivation. Fish species selection for open and closed systems would likely differ to take advantage of each systems' unique characteristics in order for the industry to be profitable.

Inorganic extractive sub-system in IMTA

Bio-filtration by aquatic plants, is assimilative, and therefore adds to the assimilative capacity of the environment for nutrients. Plants photosynthesize new biomass with solar energy and the excess nutrients which recreates a mini-ecosystem in the culture system. This, if properly balanced, plant autotrophy counters fish and microbial heterotrophy, with respect to nutrients, oxygen, pH and CO_2. Thus, plant bio-filters can stabilize the culture environment. Furthermore, farming of species that are low in food chain and that extract their nourishment from the water involves relatively low input. Seaweeds are most suitable for bio-filtration because they probably have the highest productivity of all plants and can be economically cultured.

Organic extractive species sub-system in IMTA

In a conceptual open-water integrated culture system, filter-feeding bivalves are cultured adjacent to meshed fish cages, reducing nutrient loadings by filtering and assimilating particulate wastes (fish feed and faeces) as well as phytoplankton production stimulated by introduced dissolved nutrient wastes. Waste nutrients are removed upon harvest of the cultured bivalves. With an enhanced food supply within a fish farm, there is also potential for enhancing bivalve growth and production beyond that normally expected in local waters. Therefore, integrated culture has the potential to increase the efficiency and productivity of a fish farm while reducing waste loadings and environmental impacts. The bivalve mussel, *Perna viridis* and oyster *Crassostrea madrasensis* that are commercially produced along Indian coast, can economically mitigate eutrophication in integrated aquaculture.

Advantages

- Reduce the environmental impacts
- Gives sustainable production.
- More sustainable and profitable system.
- No need for supplement feed.
- Biologically well-balanced system.
- Production of different species at one culture.

MURREL FISH FARMING- A PROFITABLE VENTURE

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Introduction

Freshwater aquaculture is an economy-generating and rural development tool. Murrel is considered to be the most economical freshwater fish species which can be cultured. They belong to the family "Channidae" and are also called snake-head fish. Murrel is one of the indigenous air-breathing fish; there is a suprabranchial accessory respiratory organ in the murrel head. It can even survive in lower dissolved oxygen levels. This fish is identified by its dark brown colour with light black stripes over the body.

Murrel fish is one of the popular freshwater and tasty fish in India. The fish has a lot of regional preferences. While it is the State fish of Telangana, people prefer murrel over any other fish in many States like Andhra Pradesh, Tamil Nadu, Punjab, Haryana and Bihar and North Eastern Region. Andhra Pradesh is the second largest fish farming region in the country with 0.8 million hectares of inland water bodies producing 1.24 MT annually. Murrel is predatory and feeds on a variety of fauna present in the water. However, the high demand and high market value and their capacity to withstand adverse weather conditions make them suitable candidate species for aquaculture. The most important aquaculture species of murrel in India is the striped murrel (*Channa striatus*), the great snakehead murrel (*Channa marulius*) and the spotted snakehead (*C. punctatus*). The culture technology is standardized for striped murrel. Murrel has high demand and high market value in India. It has a huge potential for murrel culture in freshwater areas when it is cultured with the best management practises.

Local names of murrel fish in India

Murrai (Hindi), Korameenu, Koramatta (Telugu), Viral meen (Tamil), Korava, Vatton, Varal (Malayalam), Cheng, Shol (Bengali), Maral (Marathi), Hal (Assamese) and Gadisha (Oriya).

Salient features

- High-value food fish in India and can be marketed in live condition
- Murrel culture can be done in a small backyard, shallow or community ponds
- Value-added products like fillets, pickles, curry etc. have high demand
- **Cultural practices**
- **Grow out**
- The pond should be constructed in a place having good-quality water. A pond size of 0.1-0.2 Ha is ideal for grow-out of striped murrel, with a water depth of 1 to 1.5m. Lining can be given to the pond bottom and the dyke to prevent the seepage of water. For grow-out

culture, the advisable stocking size is 5-8 cm or more with a stocking density of 10000 to 20000 / ha. The expected growth in a year is 600-700gm over a period of 8-10 months.

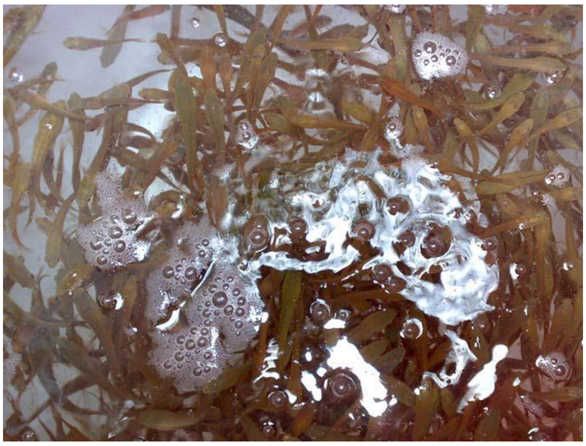
Channa marulius

Channa striatus

Channa punctatus

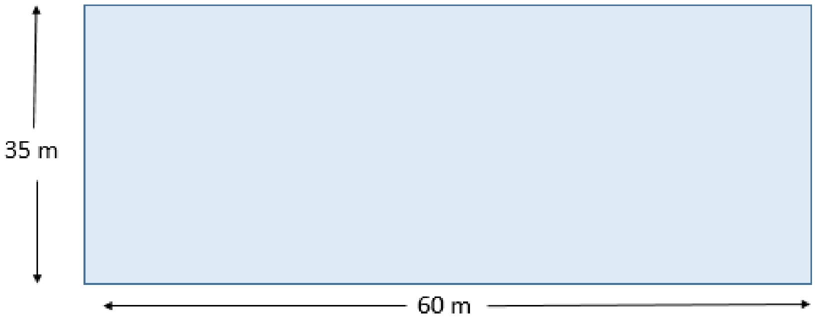
Murrel seed – early stage

Murrel seed- advanced stage



Murrel fingerlings

Length: 60m
Width: 35m
Area: 0.21 Ha
Average depth: 1.5 m



Water Temperature

For better growth of the fish and to improve the feed conversion efficiency, it is advisable to control the water temperature. Since murrel is air-breathing fishes, they can survive in less dissolved oxygen level.

Seed Collection

The murrel breeds all around the year from rain-fed ditches and shallow water bodies with rich aquatic weed vegetation. Seeds of these species, under parental care, can move in shoals in search of food along the marginal areas of the breeding environment. While moving they make characteristic ripples on the water surface which can be easily noticed from a distance. The entire shoal can be collected easily when it is moving to the marginal weed-free areas using a fine-meshed net. The fingerlings of the murrels are available in rivers, reservoirs, perennial tanks and other derelict water bodies. The present demand for murrel seed is, by and large, met from wild collections. Maximum seed availability is from May to August. The commercial culture of murrels is still not common due to inadequate seed availability. Weaned fingerlings of equal size 5-8 cm or more can be stocked in the pond. Seed suppliers/farms are available in Telangana, which can provide quality weaned seed for rearing in the captive condition.

Seed Stocking

Murrels permit high stocking density, as they are hardly fishes and tolerate overcrowding due to the additional support of air-breathing organs. The stocking density is 20,000 to 30,000 fingerlings/ha. Fishermen usually collect the murrel seed from the available natural sources and sell it to culturists. Fish farmers stock these murrel seed along with carp seed in their culture tanks and allow them to grow for 6-9 months or even more. In exclusive carps culture ponds, formers stock 300-500 murrel fingerlings per hectare to control the weed fishes, particularly tilapia fish. This gives additional income to the farmers in the state.

Feed requirement

As murrel are carnivorous, good quality protein-rich pellets can be given to the weaned fish. Feeding can be done at the rate of 5% of the body weight of fish during the initial period and 2-3 % during the later stage of culture. Good quality feed for murrel is available in the local market with high protein level and are fed on boiled chicken intestine (5-10% body weight).

Harvesting

Harvesting can be done when the fish reaches a size of 600-700 gm. Fishing nets can be used for the collection of fish from ponds. Although murrels are caught in gill nets, drag nets and cast nets, the gear mainly intended to catch murrels are long lines and various types of traps. It is also a common practice to bale out water from pools and ditches where murrels are known to live, for hand picking them.

Marketing

Murrel fish demand is very high in the market and can be sold in open markets at Rs.400-500 per kg. Consumer preferences, lucrative market value and their ability to withstand adverse water conditions make them suitable candidate species for freshwater aquaculture. It can be sold in live fish markets and hence it increases the interest among the customers.

Economics

An appropriate budget for small-scale fish farmers is given below. According to the availability of land and water, unemployed youths can excavate earthen ponds. With a minimum area of 600m^2 - 750m^2 one can earn Rs. 50,000 – 70,000/year.

Budget

Expenses	**Type I**	**Type II**
1. Construction of earthen ponds		
Pond size	15m x 10m x 1m	25m x 12m x1m
No. of ponds	5	2
Depth	1m	1m
Total area	750m	600m
Excavation	Rs.5000/pond	Rs.10000/pond
Charges	25000/5 ponds	Rs. 20000/2 ponds
Bamboo fence	Rs.1000/ponds	Rs. 4000/2 ponds
netting etc.	Rs. 5000/5 ponds	Rs. 4000/2 ponds
2. Fish fingerlings		
Size (5 cm)	150/pond	300/pond

Number	For 5 ponds 750	For 2 ponds 600
Cost of fingerlings (each Rs. 1/-)	Rs. 750	Rs. 600/-
3. Feed cost		
Chicken intestine / Fish waste	Nil	Nil
Labour		
Rs. 2000/month - For 10 months	Rs. 20000/-	Rs. 20000/-
Miscellaneous	Rs. 2250/-	Rs. 2400/-
Total expense	Rs. 53000/-	Rs. 46000/-
Total income after 10 months		
(Average survival of 80% with a table size of 1 kg and price Rs. 160 / kg)		
No. of table-size fish	600	500
Total price	96000	80000
Total Expenses	53000	46000
Net income after 10 months	43000	34000

LOACH FARMING- A LUCRATIVE BUSINESS AVENUE

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Introduction

The species *Lepidocephalus thermalis* is commonly called as Indian spiny loach and locally called as Ayirai meen. it is widespread in peninsular India and Sri Lanka. Loach is edible freshwater fish and its preferred food fish in southern part of Tamil Nadu. It consists of nutraceutical potential with good taste and flavour and it's rich in calcium, irons and other nutrients. In many places, this species is being used and consider as ornament value but in this state, it is considered as better taste inland fish so it has to fetch good price all-around in the local market. Loach has inhabitant in ponds, lake, streams and adjacent creeks of paddy fields. A species diversification is takes place important role in inland fish culture at India.

The loach fish population is getting a decrease in some regions due to subsistence fisheries, aquatic pollution, climate change, deforestation, construction of a dam across the river etc. thus species stock or population could be rehabilitated possibly by culture propagation. Since farming, carp species is alone contributing more fish production to the country, even though after reporting, much indigenous food fish availing in the nation. Therefore, the cultural practice or various farming methods of new species can emerge upon in species diversification and providing varied fish protein for as consumer preference. And spiny loach is potential species for inland cultivation in close to future and it's the optional fish species for carp culture.

Site selection

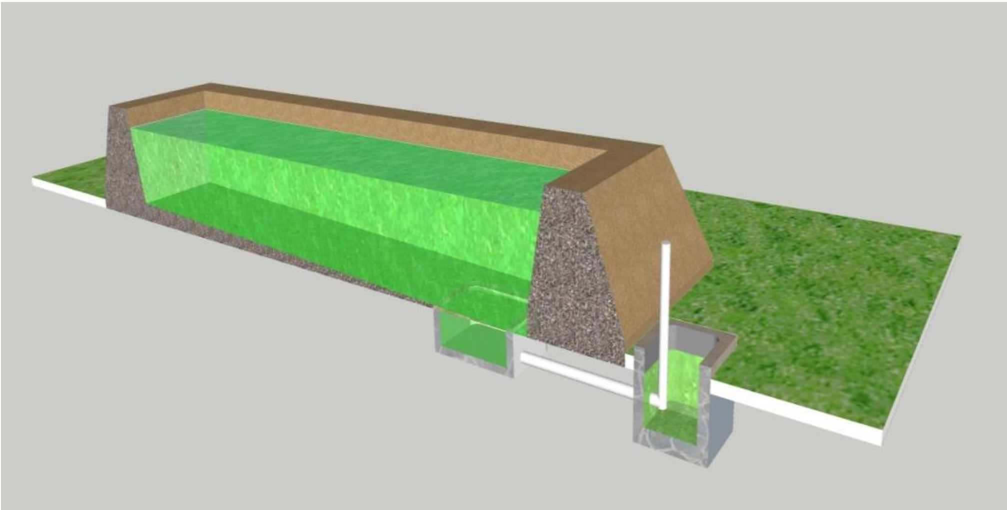
The Indian spiny loach can be cultured in earthen pond. A selection of appropriate site for fish culture is the important factor to determine the success of fish farm and before construction of fish farm water retention and soil fertility has to be taken care. Ecological factor to be considered (soil, water, topography and climate). A need pond criterion such as even earth surface, without rocks and big trees etc. are suitable area for culturing of loach in earthen pond. Selected site should have easy to access transport, electricity and low land cost. For culturing loach fish mixture of Clay: Sandy (85:15) soil is essential. In many places, the availability of sandy soil is less; in this case riverine sand can be mixed with clay and that can used for culture.

Pond preparation

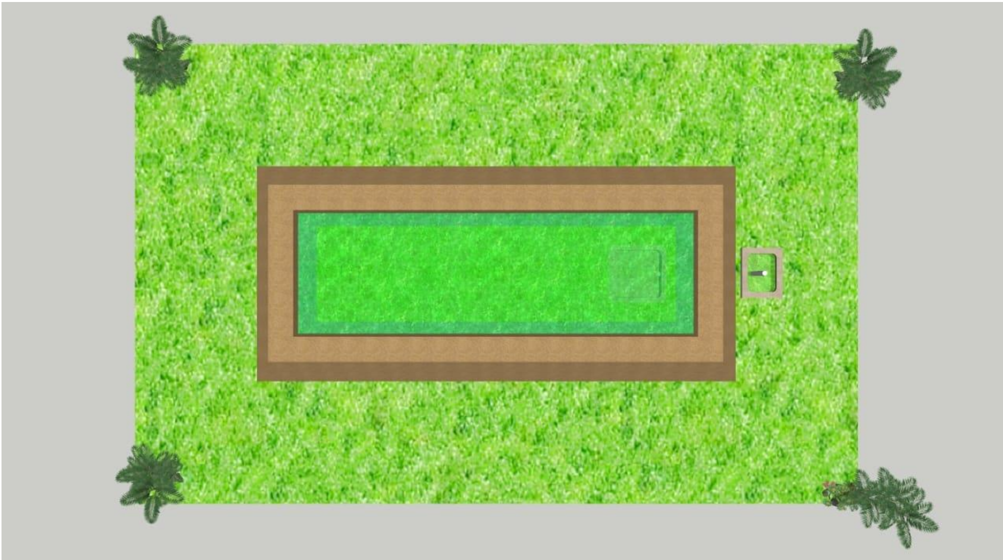
Based on water retention capacity ponds are categorized into perennial and temporary or seasonal ponds. Seasonal pond can hold the water for five to six-month duration. With the availability of water duration fish culture are also differing. Therefore, choosing of pond should be depends on species or duration of culture. The following criteria are needed for loach fish culture.

- The small size of 18 m^2 to 40 m^2 ponds are ideal for loach fish culture.

- Pond should be in rectangular shape.
- A dike entirely built of good soil and dike thickness is 30-40 cm (it should be able to resist the water pressure). It should be compact, solid and leak free.
- Pond total height is required for upto 1m
- The depth of water volume has to be maintained up to the level of 0.6m – 0.7m.
- As Should leave the free board is 0.3m is always.
- The pond bottom slope is required for complete harvesting of loach fishes. While constructing pond as dry slope deeper than wet slope (1cm (WS) :3cm (DS) is preferable).



A schematic diagram of pond bottom slope construction



An aerial of view of loach pond

A side view of Loach fish pond

By naturally this species has concealing behavior. So that the fined sand can be filled over the pond bottom as a layer up to 5 cm height of thickness for favorable fish growth. Bottom of pond should be constructed with slope towards to the outlet for Easy to dewatering the water. Outlet need to set up at bottom and its construct prior to dyke construction. Inlet are fixed top of pond and it should not take more than hours to fill the pond water. In addition to that the predatory or unwanted fishes should not entered into the pond for that inlet and outlet shall be properly knotted with fined mesh. In case of used pond, before stocking fish, the following measurement needs to be taken care;

- Removal of unwanted fishes
- Dyke Maintenance
- Inlet and outlet of pond shall be maintained properly
- Correction of pH
- Prior application of fertilization for enhancing plankton production
- If required, use recirculatory system.

Pre – Post stocking management

Application of fertilizer:

A Fertilizer application in fish pond is used to stimulate the growth of plankton and fish production. These are used as two form natural (organic) or synthetic substance (inorganic). The quality of water is very much essential for any fish culture. The application of fertilizer depends on certain water quality characteristics.

i. Organic fertilizer

Once filled the pond water, the water quality is need to be assessed, based on these result, application & usage of lime quantity can be calculated. Lime application is used to correct the water pH level in pond. In addition, it’s releasing the nutrient into soil and water and balancing the pH. Lime is help to fastening the decaying process in the pond bottom due to this soil nutrients become enriched. After 15 days of lime application, organic fertilizer has to be applied in pond. Organic fertilizer contains mixture of organic matter and mineral nutrient they produce locally from farm animal. Cow dung manure are mainly used in fish culture pond. It's the best manure in among the animal manure. Raw cow dung (wet) is the best manure for application. Small scale fish farm are mostly rely on these fertilizer because of low cost and local availability.

ii. Inorganic fertilizer

The application strategies of fertilization are depending on pond substratum and their optimum level are different from region to region, moreover it's based on soil chemistry. Application of inorganic fertilization is enhancing the primary production in pond. These fertilizers are containing fixed nutrient composition and it possess high solubility in water and after application it cause rapid reaction with pond water. It should be used alternative with organic manure. Inorganic fertilizer is categorized into three that is nitrogen, phosphorus and potassium. As ammonium sulphate, calcium ammonium nitrate and urea these fertilizers are used in pond to enhancing the nutrient of nitrogen and it is application should be adhere based on soil pH. A freshwater limiting nutrient is phosphorus therefore very low level occur in pond; to enhancing these nutrient super phosphates is added, these fertilize is leaching the nutrient slowly into the water and providing phosphorus along calcium nutrients. An application of inorganic fertilizer should be based on the water quality and fish behavior and its application dosage level is given below table as example.

S. No	Area	Nitrogen (urea) / kg	Phosphorus (super phosphate) /kg	Potassium (potassium chloride) / kg	Cow dung (kg)
1.	0.25 acre	5. 06	5.06	2.55	1012.1

*If needed go for application of inorganic fertilization with the consultation of Aquaculture scientist.

Water quality

The success of fish culture is dependent on water quality. A poor water quality can affect the fish health, reproduction and growth in any culture system. So fish farmer should have knowledge in management of pond water quality. Loach fish can able to tolerate and grow in slight acidic, neutral and slight alkaline condition. Particularly these species lives under plants and detritus matter; pH and hard water are does not affect much. Pond water level should be maintained minimum 2 feet for loach culture. Aquatic weeds like Azolla can be cultured in loach fish pond, it's provide favorable environment condition to the fish and also help to reduce excess available nutrients in pond. The optimum water quality parameter is depicted in the table below,

Parameters	Favorable Level
Temperature	27 – 29 degree Celsius
Dissolved oxygen	> 4 ppm
pH	6.5 – 8.5

Hardness	165 ppm
Ammonia	0.01 ppm
Nitrate	< 5 ppm
Nitrite	< 0.05 ppm

Stocking

Based on the preliminary study and farmers trail studies the following stocking densities were determined for loach culture in earthen ponds. Despite, it can breed naturally, there is a possibility for variation in final biomass harvest from pond to pond. The preferable stocking rate is 70-72 gm (0.4 -0.5g/fish wt.) of loach in 1 square meter. At the end of three-month culture duration able to harvest approx. 225 – 230 gm/ square meter. While harvesting partial harvest methods is recommended to avoid animal shortage for stocking.

Feeding

Loach fish is an omnivorous. In natural system, it is mainly feeding on detritus, plankton, insects etc. if it is adopted under captivity can also feeding supplementary diet as well. If fishes are cultured with more stocking density then supplementary feeding is necessary to meet out the feed demands by the animal. In any culture system, supplementary feed should provide twice in day with 6-7 % of fish body weight.

If fish weight is reached beyond 1.5 gm then 2-3% of fish body weight is preferable. A significant fish growth can be achieved through best feed management practices. Supplementary feed should contain mixture of all macro and micro nutrient composition for better growth of fish, especially for loach fish 35% of protein is recommended and it provide significant contribution to fish growth. Farmer trials recommending Ground nut oil cake (GNOC) and Cotton seed cake (CSOC) with 60:40 ratio, this feed composition is help to attained quick maturity of fish and breed naturally in culture system. And also, half grained rice particles can also use as supplement diet in culture system.

Harvesting

After 3-5 months these species is ready to harvest from culture pond. The suitable size for harvest is above 5 cm. A getting loach young one are very difficult. Therefore, the partial harvest has to be done in culture pond, otherwise it is, better to maintain additional fish pond is required for stocking. So that the seed crisis could be manageable. Harvest can be done after complete dewatering of culture pond.

Conclusion

Indian spiny Loach is suitable candidate species for scarcity of water and land prevailing area. And almost considered as hardy. Also suitable for poly-culture with carp fry. It has more consumer preference and fetch high market price. It is an alternative species for carp and other inland fish cultures. it might be contributing to the species diversification and future candidate in aquaculture industries.

PERIPHYTON-BASED FISH FARMING

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Supplementary Feed-Based Fish Culture

Aquaculture, especially commercial fish culture, is not always truly sustainable because of the supply of external feeds, chemicals and energy inputs. In commercial fish culture, the demand for artificial feeds is met by processed pellets that are made of fishmeal, fish oil and grain. Aquaculture, with a major production shared by fish, consumes more than 63 % of fishmeal and 81 % of fish oil than other meat production industries. The knowledge of feeding preferences by fish on naturally available food is scientifically inadequate and farmers always tend to use supplementary feed to increase income per unit area. Such effort, in general, leads to detrimental effects on the aquatic environment. The level of total ammonia nitrogen (TAN) and nitrite - nitrogen increased with increasing biomass and supplementary feed consumption in the pond system. Dissolved oxygen in ponds with organic fertilizer was reported significantly lower production than that in ponds with inorganic input. In addition, the marginal and poor fish farmers are unable to afford the extra cost of available supplementary fish feeds. The cost of feed is one of the major expenses in any fish culture operation as the profitability of the whole practice remains intricately tied to it. Although formulated fish feeds are considered the most balanced and suitable feed, because of the high cost, the farmers are now compelled or forced to search for cheaper alternative protein sources of either animal or vegetable origin.

External inputs – Problems

Fish metabolism and leaching of organic substances from food and faeces might cause poor water quality and pond bottom deterioration because of the inverse relationship between food assimilation efficiency and culture density. The majority of the fish farmers in Asia are unable to procure expensive inputs like formulated feeds. Instead, cheap organic wastes produced on-farm or within the household can be used. But the conversion efficiencies are in general low, reaching 20% at best. The rest is discharged or accumulates in the sediment and only a minor fraction is subsequently recycled within the farming system. Water exchange rate increases the operating costs due to the high water and energy consumption and the lower retention time of nutrients within the culture systems.

Periphyton - An alternative to supplementary feed?

Periphyton plays a major role in adopting feeding strategy of ‘as and when needed’ type of food in aquaculture, especially for herbivorous and periphytophagous fish species for last one decade. Production of attached algae per unit water surface area is also higher than phytoplankton. The possibility of consuming periphyton by fish is more, especially the algae.

This could be due to the attached algae which are generally more stable than phytoplankton and the risk of collapse is much lower. Herbivorous aquatic animals, especially fish, feeds largely on benthic, epilithic or epiphytic algae rather than phytoplankton. Irrespective of morphological orientation for filter feeding or browsing, the feeding intensity of fish increases in periphytic than plankton environment. Thus, fish has to be essentially periphytophagous by nature in periphyton based fish culture is not always important, as their finding laid down the basis of selecting a non-periphytophagous fish in a periphytic based fish culture. Periphyton plays a major role in aquaculture, especially for her bivorous and periphytophagous fish species for last one decade.

Periphyton

It is the complex of sessile aquatic biota with associated detritus, attached to submerged substrates. It includes phytoplankton, zooplankton and other bottom organisms in combination with microbial bio-films. In aquaculture, the substrate can be anything ranging from coral reefs, stones, branches from any tree or shrub species, higher aquatic plants, bamboo, plastics, etc.

The positive effect of substrate based periphyton on the overall pond ecology along with the higher production supports low input cost involved in periphyton based ponds, makes it a reliable production system. Because of their utilization of nutrients through autotrophic and heterotrophic processes that accelerates the removal of organic and inorganic wastes lead to improve the water quality and their biomass can be used as a source of food by the cultivated organisms. In summary, the benefits exerted from periphyton based ponds are periphyton as additional natural food, substrates as shelter to minimise territorial effects and improved water quality through trapping suspended solids, organic matter breakdown and enhanced nitrification.

Nutrition composition of periphyton

The average protein content of 15 % was estimated in periphyton collected from coral reefs. It was reported that 28-55 % protein and 5-18 % lipid in some algal species of periphytic nature. It has been found that EPS of biofilm accounted for 50-80 % of the total organic matter, therefore, leading to a high amount of carbohydrates. Scientists recorded as low as 2-3 % protein, 0.04-0.29 % lipid and 29-33 % carbohydrate in periphyton grown on stones. The Ash content of periphyton is known to increase as the community grows older. The crude protein from periphyton grown on the bamboo substrate was 27.19%, 14.63 % protein in Hizol (*Barringtonia* sp.) branches, 18.74 % on Kanchi (bamboo side shoot) and 12.69 % protein on jute stick. Periphytic fat content recorded as 5.43 %, 0.35 % and 2.75 %, respectively on substrates of Hizol, Kanchi and Jute stick. It was observed that ash content from periphyton on bamboo was 29%, Hizol was 41%, Kanchi was 29% and jute stick was 31.12%. The nutrient quality and availability on periphyton varies with several factors like grazing pressure, algal and bacterial taxonomic composition, nutrient level of environment, environmental purity and most significantly to substrate type. Others also recorded protein level of 19.27 to 35.56% in periphyton. Protein, lipid and fat content of algae were also reported as 35 to 63%, 10 to 57% and 2 to 22% respectively. The ash content also shows variation with a range from 17.45 to 41%.

Culture Techniques

Initially, the ponds have to be cleaned well and disinfected with sodium hypochlorite at 60 ppm. Then introduce and fix all the substrates vertically into the same pond with equal space between the substrates. After installation of all the substrates, fill the pond with water. Apply quick lime (CaO) to the pond at the rate of 250 kg/ha. Three days after liming, ponds must be fertilized with cow dung at the rate of 1,500 kg/ha. The application of cow dung should be continued once in 10 days at same dosage rate throughout the culture period until development of periphyton. After 2 weeks periphyton will be developed on the substrates and the animal can be stocked.

Substrates for periphyton development

Many trials have demonstrated that fish production from the ponds provided with substrate for periphyton is higher than that of substrate free ponds. A positive effect of periphyton on growth of rohu was recorded using three plant substrates such as sugarcane bagasse, paddy straw and dried *Eichhornia*. The species also performed well when the substrate employed with bamboo with the production being 1.7 times higher in treatment with bamboo, recording 1899 kg / ha for 4 months. Artificially, plastic baffles and bamboo poles were used to increase the attachment of microbial biomass. It has been observed that fish production based on periphyton depends on artificial substrate type and preferred to use bamboo rather than PVC pipes and sugarcane bagasse bundles when culturing masheer (*Tor khudree*) fingerlings.

Fish species combinations

Not all fish species are equally efficient in exploiting periphyton communities, and some species have complementary feeding niches within the pond ecosystem. In Bangladesh, the traditional indigenous major carp species used in polyculture systems will be tested in periphyton based production systems. As preliminary screening, the surface feeder catla, *Catla catla*, the column feeder rohu, *Labeo rohita*, and the bottom feeder calbaush, *Morulius calbasu*, Preliminary results showed that on average, monoculture of calbaush and rohu yield an 80% higher production in periphyton systems compared to control ponds without substrate. In addition, in periphyton systems the duo-culture of rohu (60%) and catla (40%) resulted in a 3-month production of 650 kg/ha compared to a production of 320 and 280 kg/ha in monoculture of rohu and catla, respectively. In these trials, the total stocking density in all ponds was equal. Other species such as Tilapia, Freshwater prawn, shrimp, Salmon, etc are suitable for periphyton based aquaculture.

Water Quality in Substrate - Based Systems

Water quality is an integral part of any aquaculture system since any deterioration in water quality due to improper feed / fertilization management would bring about stress to fish predisposing them to attack by pathogens. Nitrogenous wastes are excreted by fish in several forms such as ammonia, creatine, free amino acid, urea and uric acid. Low dissolved oxygen is characteristic of water with predominant heterotrophic food production which accounts for bulk of oxygen consumption. In traditional aquaculture ponds, nitrification occurs mostly at the sediment surface and is limited not only by surface area but also by oxygen availability. In addition, fast growing heterotrophic bacteria might limit the space needed by the slow growing chemo-autotrophic nitrifying bacteria. If insufficient nitrification takes place, ammonia toxicity can develop which is still one of the major constraints to intensifying pond aquaculture.

Bacterial biofilm developed on substrate might have brought down ammonia concentration by nitrification process. Periphyton is a complex mixture of autotrophic and heterotrophic organisms and cannot simply be regarded as an attached equivalent of phytoplankton, although it certainly performs similar functions, such as oxygen production and the uptake of inorganic nutrients. There is an intense exchange of inorganic and organic solutes between autotrophic and heterotrophic components within the periphyton assemblage, and solids can be trapped by the periphytic biofilms, reducing the accumulation of organic matter on the bottom in periphyton-based ponds.

Biofilm acts as a biofilter by lodging high density of nitrifying *Nitrosomonas* sp and *Nitrobacter* sp. In substrate based ponds, nitrifying bacteria develop on the substrates which are located in the water column where more oxygen is available than at the water sediment interface. Therefore, periphytic biofilms enhance nitrification, keeping ammonia levels low.

Advantages

- Increase the growth of the animal
- Increase the overall production in the culture pond
- Reduce the production cost
- Create the natural environment in the system
- Providing shelter to the animal in the culture ponds
- Improve the water quality in the system
- It provides natural food to the animal in the culture pond
- It maintains the food chain in the ecosystem.

Economic Benefit

In periphyton based aquaculture, the labour cost required for periphyton is higher than the control pond, which is due to the additional requirement of labour for installation of substrate. Around 10% reduction in total feed cost was noticed in periphyton pond when compared with the control pond. This could be due to the improved FCR, which is linked with the reduction of feed wastage in periphyton pond. The presences of periphyton in the pond is acts as a supplementary feed for the cultured organisms and also improvise the settlement of feed over the vertical substrates, which increases the feed availability time and reduce the feed wastage. It has been noted that both periphyton along with the carbon addition has the capacity to improve the health and enhance the growth of shrimp. This excludes the usage of probiotics and medicine which costs around 2.5-4.66% of total costs in the culture. The low electricity cost in periphyton pond was due to the reduced operation of aerators. The increased DO concentration due to the algal activity reduced the running time of the aerator during morning hours ultimately made the electricity costs less than that of control pond which is purely plankton based. The total variable costs of periphyton pond were lower than the control pond. It is mainly due to the reduced aeration rates, and feeding rates by the periphyton biomass. In brief, addition of substrate provides additional shelter, natural food in the form of periphyton and also improves the environmental conditions which could improves the production of shrimp from periphyton pond about 1.2 times higher than that of control pond. This leads to the generation of more net income by periphyton pond (1.5 times higher) than the control pond. BCR (Benefit – Cost Ratio) of the periphyton pond is higher than the control pond. Coastal Aquaculture Authority (CAA), India, it is mandatory that the effluent from the aquaculture pond should be treated before releasing into the adjacent environment. By means of periphyton technology, the effluent nitrogen concentration was greatly reduced by 19% when compared to conventional shrimp culture. Therefore, the cost of operating the ETS (Effluent Treatment System) will be excluded from the periphyton-based aquaculture system and it facilitates the farmers to earn more profit in a sustainable manner.

SHRIMP FARMING – AN OVERVIEW

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Introduction

Aquaculture production has grown enormously in recent years and among that Penaeid shrimps are one of the most important cultured species worldwide especially in Asia due to their high economic value and export .A new shrimp species *Penaeus vannamei* species introduced and culture practice has been carried out in many coastal states of India last few years. Presently it is dominated 90 % of total shrimp culture. The penaeid shrimp *Penaeus vannamei* exhibits fast growth rate and its culture period is significantly reduces compared to *Penaeus monodon*, thus the *Penaeus vannamei* has been established as alternative to *Penaeus monodon* to shrimp farming in several countries.

Pond Preparation

The pond bottom of newly developed and excavated pond are treated with high dose of lime powder around 400- 500 kg / one hectare areas. For culture pond after harvest, the pond bottom is allowed to dry and crack to promote the capacity of the hydrogen sulphide and to eradicate the micro or macro organisms and other predators. The scraping of pond bottom is made up to 3-4 inches and special in zone of high organic black soil areas. The scraping black soils are removed and thrown away from the pond side. Then the pond bottom is thoroughly ploughed at a depth of 30 cm to remove the obnoxious gases existing in the soil. The pond bottom is treated with lime as well as bleaching powders. For liming, farmers can use quick lime, agricultural lime and dolomite. The saline water can be entered to the pond through pumping after fine filtration systems up to 3-4 ft water level. The filled water has treated with Chlorine at 20 ppm-30 ppm and left for one week. The pond water has conditioned with minerals, probiotic, etc before stocking.

Pond Preparation: Pond Bottom Drying, Tilting and Liming

Biosecurity

Certain extent of bio security measures can be carried out in farms like bird netting, crab fencing etc to ensure biosecurity.

Stocking

The stocking of quality *P. vannamei* PL12 – PL16 can be procured from the shrimp hatcheries after quality and PCR tests. The shrimp post larvae can be transported from hatcheries to culture ponds by air cool vehicle. The stocking of post larvae are undertaken after proper acclimitzation process.

Stocking Density

The stocking density of shrimp post larvae in most of the ponds are in range of 70 -100 nos/m^2. Also highest stocking density of shrimp post larvae in some of ponds are above 120 to 150 nos/m^2.

Feeding

The all the farms used formulated commercial pellet shrimp feeds from various companies for routine feeding purposes. Maximum number of farms adopted a combination of broadcasting and check tray method as feeding strategies. Regularly the daily feeding are adjusted as per the check tray observations. Feeding frequencies mostly adopted by the maximum farms at 4 times day and according prescribed feed chart of individual feed companies.

Water Exchange

Water level can be maintained from 1.0 - 1.3 meter throughout culture period by adding water to pond through pumping from near water source due to evaporation losses or seepage losses etc. Most of ponds are not able to make water exchange in regular basis due to non-availability of quality saline water adjacent to their pond side. However, some extent of drainage from pond can be undertaken in case of very poor water quality or severity of shrimp health conditions.

Aeration

1-3 no of paddle wheel aerators of 1 HP and one spiral paddle wheel aerators can be fixed according to farm size and stocking density in different corner of pond. The aerators are under operation around 8-12 hours per day for aeration purposes during entire culture period. Paddle wheel aerators are provided per pond to create water current for the accumulation of wastes in the center of the pond and to increase the dissolved oxygen in the water column. Aerators can be placed away from the dykes and almost 40 meter distance from each other.

Water and Soil Treatments

After stocking, the soil & water probiotics, Minerals, Zeolites, ammonia reducer compounds, Dissolved Oxygen (DO) enhancer compounds, water disinfectants are widely used in pond water periodically in regular intervals based on the water & soil quality and condition of shrimp health. The pond bottom sediment turns black color (Sludges) according to the increases of culture days and increase rate of feeding dose. The sludge formation is controlled in pond by applying sludge digesting probiotic products from various commercial companies. The various feed supplements are applied along with pellet feed and fed to shrimps for promotion of growth, avoiding loose or soft shell, prevents diseases etc.

Aeration in shrimp ponds

Application of home-made juice

A homemade juice can be applied once in a week. 8 kg of sugarcane jiggery, 20 kg of rice bran, 32 kg of dolomite, 200 gm of yeast powder, 500 gm of curd are mixed thoroughly in an earthen tub and soaked for 1-2 days and applied to tank water @ 30 lt/tank to keep the tank environment at optimum level.

Shrimp culture Pond views

Range of Water Quality Parameters

The major water parameter are measured and recorded in daily or weekly by the help of field testing instruments and test kits. The major water quality parameters like salinity, dissolved oxygen, pH, temperature and total ammonia nitrogen (TAN) are monitored in regular intervals. The major water parameters of most of ponds are in following range.

Water Parameters	Value Range
pH	7.4- 9.4
Salinity(ppt)	5.0-35.0
Dissolved Oxygen (mg/lit)	3.6 – 6.5
Ammonia (ppm)	0.1 -2.4
Temperature ^{0}C	24.0 – 32.0

Sampling

Weekly sampling is very important to know the shrimp health, growth and survival. The first sampling has been carried out in all ponds at the 60 DOC onwards of the culture. During sampling the growth & survivals of the shrimps has varied depends on the stocking density.


Feed Check tray and Sampling by cast net

Growth and Survival

Sampling has undertaken in the pond fortnightly during early hours of the day with cast net after 60 DOC in most of ponds. Four to five hauls are made in each pond. The individual weight of shrimp are observed and assessed the other health matters like healthiness, survivals, moults, average body weight (ABW), diseases or infections etc . The average shrimp body growth rate are in range 18 gm -20 gm in 90 days of culture with survivals of 70-90 %. The final shrimp production rate ranges from 12.0 ton to 24 ton/hectare depending stocking density, growth rate and % of survivals.

Harvest and Marketing

Shrimps are harvested by the drag nets in most of the ponds. The harvested shrimps are packed with ice in trays after proper washing in fresh water. The shrimps are sold according the count and size.


Shrimp Harvesting by drag net

RECENT ISSUES AND INNOVATION IN SHRIMP FARMING

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Introduction

The shrimp farming industry globally faces numerous challenges, most importantly various viral, bacterial and fungal diseases; also, the need for additional, novel ingredients that will be needed to manufacture and support a growing demand for aqua feeds; and environmental impact, markets and investment issues.

Diseases and aqua feed ingredients are undoubtedly the most important challenges currently faced by the shrimp industry. The history of the industry has been one of serious, periodic global pandemics and diseases have been a significant industry driver from the beginning. Various diseases will continue to be relevant drivers, but when we examine the industry's tract record over the last two decades of commercial existence – when production has been quadrupled or more – despite facing various serious diseases, we know the industry will continue to learn how to manage and coexist with disease as it keeps growing globally.

The last decade or so has seen the emergence of two new and very serious diseases, the EMS/AHPND disease (Early Mortality Syndrome/Acute Hepatopancreatic Necrosis Disease) caused by a bacterium, *Vibrio parahaemolyticus*; and a new disease called Hepatopancreatic Microsporidiosis (HPM) caused by a small (1 micron), intracellular, spore-forming microsporidian parasite (*Enterocytozoon hepatopenaei*, or EHP). Countries like Thailand and others have shown the way regarding how to successfully manage these new diseases. But it is very important that various countries where these diseases are very likely present acknowledge their presence as the first step to effectively managing them.

The availability of enough aquafeed ingredients is the other major challenge I think requires attention. Aquafeed demand has expanded significantly during the last three decades – the FAO's The State of World Fisheries and Aquaculture 2016 report shows that production of farmed, fed aquatic species is growing significantly – and current global aquafeed production is about 4 percent of the global animal feed production of 1.08 billion metric tons, according to the 2018 Alltech Global Feed Survey.

The future, today

Improving shrimp lines is a top consideration and farmed shrimp species have much potential for further genetic improvement through a variety of old and new technologies, including traditional genetic technologies like selective breeding, genome-based genetic selection and more the advanced genome editing tools like CRISPR/Cas9 (Clustered Regularly Inter-spaced Short Palindromic Repeats) and TALEN (Transcription activator-like effector nucleases) – all of which can lead to gains in growth rates, resistance and other desirable selection traits.

Shrimp's relatively short generation time greatly assists in their selective breeding efforts. The development of improved lines of specific pathogen-free (SPF), specific pathogen-resistant (SPR) and specific pathogen-tolerant (SPT) animals, and breeding for improved performance in specific culture environments will continue to be relevant, as will be increased application of genomics, nutrigenomics and proteomics.

Healthier shrimp are possible through improved biosecurity, from pond to zone management. Other areas for improvement include better pathogen detection and a better understanding of their mode of action; effective use of immunostimulants and probiotics, and even the development of vaccines now appears not so far-fetched.

There is much room to improve grow-out technologies by increasing water reuse and with multi-phased production strategies using nursery systems. The industry can expand by growing near major consumption centers and through intensification, just like Guatemalan shrimp farmers are doing.

Our knowledge of shrimp's nutritional requirements continues to expand, with a better understanding of the relevance of gut health. Novel ingredients and improved feed manufacturing processes, functional feeds (targeting seasons, stress, immunomodulation and others), with improved delivery/management of feeds including precision feeding and automated feeding systems, which are quickly gaining much popularity as their numerous benefits are better understood.

Regarding global shrimp markets, we can definitively expand them, but we need to offer consistent availability and quality, as well as more, novel value-added, "convenient" products. Gaining market share in the growing fast-food sector is key to expand shrimp demand and consumption; and as well, shrimp can and should increase its presence in the domestic markets of many countries. New technologies like those that can extend the shelf-life of fresh products (e.g. modified atmosphere packaging) have the potential to transform how we package, transport, store and market our products.

Perspectives

Shrimp hatcheries must better address the issue of live foods production, including increased replacement of live feeds and biosecurity. The grow-out segment must work to reduce the culture time through selective breeding, improved production management, efficiency, biosecurity, health management and survival.

Diseases are part of the industry and many new support technologies – including developments in genetic improvement and selection of cultured animals and a variety of species that provide feed ingredients – will help the industry grow in many regions with appropriate investment and market development. Shrimp markets and global consumption can be expanded by developing internal markets and new export markets in Asia, Africa, the Middle East and other areas. New and more convenient, ready-to-eat products, new packaging and transport technologies, and better promotion (telling our story better) will help expand markets and consumption.

Innovations

New technology and innovations can have tangible, lasting impact on an industry trending towards energy and cost efficiency with less risks.

1. Infrastructure

Modern farmers are gradually preferring lined ponds to substantially increase biomass carrying capacity, but these liners are expensive and not always as durable as claimed. In lined ponds, water and waste may leak through tears in the lining and remain stagnant under the pond lining on top of soil. The stagnant water and moist soil become anoxic, producing toxic gases. Subsequently, these toxic gases diffuse back into the shrimp pond though the damaged lining and trigger shrimp stress and mortality. Already working on thin margins, farmers face additional costs of removing the anoxic soil and replacing/ repairing liners between crop cycles.

As a solution, the new woven and flexible geomembrane plastic liners, though available for purchase, are logistically or financially inaccessible to most. This is a new material in the market which farmers, especially in China, are adopting. The material is stronger, more durable and easier to fix, according to farmers using them. Thus, there is an opportunity of wider distribution of affordable and durable liners. New technology to monitor the liquid and gas below their pond linings could also help farmers plan for repairs.

Separately, improvements in nursery practices and any technological advancement will increase inclusion of on-site nurseries in farm infrastructure. Innovations that help more farmers to add nursery systems to their current operations will overall be beneficial.

2. Operations and communication

Various opportunities for innovation in farm operations and communications systems exist. Cheap, user-friendly, smartphone-compatible and reliable applications can empower farmers to make informed decisions and forecast production. Integrated mobile apps could monitor shrimp behaviour, health and nutritional requirements, while tracking environmental conditions and farm inventory.

Currently, operational information is shared via text or verbally. Solutions to organise historical data records could standardise production protocols and image analysis of photos of written information can automate the digitalisation of farm records. With better management, farmers may track performance parameters, which in turn is useful for financial and insurance products to be introduced to the sector. Any one or a combination of the above will help farmers to better plan, manage, and communicate tasks for successful farm operations and harvests.

3. Power supply, control and consumption

Farmers do not actively measure their electricity consumption in general. A solution for widespread monitoring of power would likely come in the form of mobile applications. Farmers could forecast the monthly energy costs and even be prepared to deal with power failures. This mitigates the risks associated with power failures, chief of which is increased mortality due to reduced aeration.

More advanced apps would grant farmers the ability to control and regulate the power usage of individual devices (e.g. aerators) remotely. Farmers could optimise device use and schedule maintenance according to the device usage to avoid expensive repairs or replacements. Overall, greater cost savings would be achieved through lower energy use, currently a significant operational cost in intensive farms.

4. Water logistics

There are a few opportunities to improve water supply and water logistics technology. Improved pump efficiency is needed by farmers as pumps contribute significantly to energy costs. Making pumps more cost efficient, affordable and durable is a priority. Additionally, there is a need for enhanced monitoring and control systems. Pumps controlled by timers and built-in sensors for flow rate and water levels can mitigate the risk of pump failure during critical production periods.

Farmers on large and remote farms would especially benefit from remote-controlled pumps and make changes according to real-time feedback of pond levels and tidal regimes. Thai farmers use pond recirculation systems to recycle and reuse production pond water. If more farmers capitalise on unused ponds for on-farm water recycling, the water footprint of shrimp farming will be lowered substantially.

5. Aeration

Along with water pumps, aerators consume the most energy on shrimp farms. Aerators that are both cost-efficient and effective at increasing dissolved oxygen are welcomed by farmers. Sensors monitoring energy consumption of aerators and dissolved oxygen concentration will enable farmers to optimise energy use.

A farmer Thailand inspects his post larvae in his indoor nursery controlled by auto feeders, aeration and monitored by CCTV cameras.

The primary issue with aerators is corrosion of motors and moving components due to saline conditions. Corrosion resistant motors or aerators in general would solve the problem of constant expenditure on repairing or replacing aerator parts. With remote monitoring of the mechanical performance of aerators, farms can also plan adequate maintenance schedules.

New aerators on the market have gearless motors with few moving parts and promise to be long lasting. However, farmers still prefer to repair and refurbish old motors until they are presented with a proven, cost-effective solution. There is huge potential for innovations to support farmers' needs in this regard.

6. Feed

Feed is the highest cost for shrimp farmers. Optimising for feed consumption is thus crucial, not only to save costs but to limit excess nutrients in ponds. Observation of feeding behaviour and shrimp gut manually using check trays is to understand feed consumption. Some companies have integrated acoustic sensors with autofeeders to ascertain when the shrimp feed and then time feeding accordingly. Still, costs of these auto-feeders are prohibitive. As such, affordable and accessible innovation options for farmers would be immensely beneficial for farmers.

Existing non-remote auto-feeders are challenging to operate for staff because of the need to predict feeding rates in a day. Ineffective communication among staff can lead to incorrect feeding amounts. Improved auto-feeders would further streamline farm operations and mitigate ineffective feeding.

User-friendly sensors that measure shrimp biomass, movement, and feeding behaviour, can be integrated with management platforms to aid farmers in planning feed volumes and schedules. These tools should be simple to use, easy to install, durable in corrosive saline conditions and compatible with smartphones.

7. Water quality and shrimp health monitoring

Multiple physical and chemical parameters influence physiological processes of the shrimp. Farmers need accurate, real-time information on water quality and shrimp health to make operational decisions. Most farmers rely on manual colorimetric test kits to measure water parameters and are unable to obtain quick results.

Currently, newer methods are needed for faster, more accurate and more frequent data measurements along with information collection, storage and analysis. New technology should automate the collection, storage, and analysis of environmental and health data as farmers lack the capacity to maintain their monitoring records. Several mobile apps and sensors with integrated water and health monitoring exist, but these solutions need to be further optimised for user experience.

8. Monitoring growth

Measuring growth rate of shrimp directly predicts multiple financial outcomes as farmers can determine the amount of feed required and the ultimate value of their current production cycle (the higher the count, the higher the price of the harvest). This is an immense opportunity for innovation.

Image recognition tools are already used in the production of other species in clearer water, but the limited visibility of turbid water used in shrimp farming restricts the use of existing technology.

One startup, XpertSea, has a device that analyses images of live shrimp to inform farmers on shrimp sizes, weight, growth rates and size distributions. However, this device is currently not used *in situ* so new innovations that conduct real-time underwater monitoring of shrimp would reduce the labour required to collect growth data. Naturally, this technology could also predict appropriate harvesting times for each production cycle.

9. Market size and harvesting

As mentioned in the previous section, there is great potential for digital *in situ* monitoring of shrimp biomass to predict harvest volumes and sizes. This also allows for more accurate feeding in terms of timing and feed quantity. Processing companies can receive information in advance to plan their operations and farmers will have higher negotiation power in price discussions with buyers. As market demand for different shrimp size classes fluctuates, knowing the size distribution of a particular crop allows farmers to set harvest dates that optimise for selling price. In-situ monitoring also negates the need for collectors to move sampling gear from farm-to-farm, thereby removing the risk of cross-contamination.

Faster methods to harvest shrimp are highly desirable for it reduces stress to the animal during harvesting and can hence improve flesh quality. Mechanical harvest pumps can gather up to 10 tonnes per hour and produce better margins potentially. This typically requires 4 to 5 hours if done manually with more manpower. On a separate note, large drainage pumps will likely be more available for farms that do not have sluice gates to drain ponds. This is already commonly used in Thailand.

Final thoughts

The impact of COVID-19 on the shrimp sector cannot be overstated. The shrimp trade has declined significantly, leading to the largest declines in the farm-gate and export prices in the past decade. This disruption, however, could be the impetus for farmers to overhaul production methods and incorporate new innovations. Operating effectively and efficiently is arguably more important now for shrimp farmers and the industry at large.

Importantly, solution providers must understand how farmers work with service providers from a supply chain perspective to effectively engage and provide value for farmers in each country.

FISH FEED PREPARATION AND FEEDING TECHNIQUES

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The most important aspect of fish culture is providing good quality nutritious feed in the correct amounts to the fishes. Feed must be nutritionally complete and kept fresh. Feed must provide all necessary proteins, essential amino acids, carbohydrates, fats, essential fatty acids, vitamins and minerals for maximum growth. Nutrients start to deteriorate quickly when exposed to heat and moisture.

Selection of feed ingredients for feed preparation

To select the feed ingredients, the following major factors are considered to manufacture fish feeds in both commercial as well as on farm levels.

1. Supply of regular and locally available ingredients
2. Suitability of ingredients as per nutritional requirements and species.
3. Effective cost of feed ingredients (cost of raw materials, transportation charges etc)
4. Handling and processing requirement prior to feeding, including transportation should be minimal or negligible.
5. Freshness of the ingredients should be fresh and should not have any off flavor. The moisture content of the ingredients should be within a range of 10-13 %. Above this moisture level fungus growth may take place.

Good feed depends on the quality of the ingredients. So consumer decision for selection of the ingredients plays a major role to extract more profit from the culture system.

Locally available ingredients

Regular supply of ingredients is very important for reducing the cost of feed. Locally available ingredients further reduce the cost of manufacturing.

Suitability of ingredients

A wide range of various available ingredients can be used applying trial and error methods. Main sources of high protein ingredients are available in animal as well as in plant origin. Each species requires different energy as well as dietary requirements and to meet this, a suitable diet must be prepared. To prepare a suitable balance feed the assessment of ingredient quality is very much desired. A real as well as theoretical analysis of ingredients should be known to decide the suitability of ingredients to fish.

Effective cost of ingredients

The cost of the ingredients varies depending on various factors, eg, availability of ingredients on different locations, moisture content of plant ingredients, regular supply and demand etc.

Extrusion

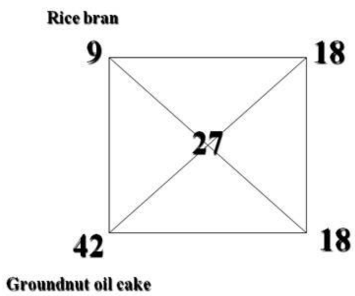
Extrusion cooking is a high-temperature short-time process in which a final product is obtained by heating, mixing, shearing, and forcing material through a die. The rate and extent of heating, mixing, shearing, and compressing of the materials inside the barrel and subsequently the die is strongly related to the properties of the raw materials and process conditions used. All the ingredients are preconditioned with steam before extrusion. Hence, understanding the physical, rheological, and chemical properties of an ingredient melt inside the barrel is very important for product development, process control, final product quality and scaling up operations. Each material exhibits distinct behaviour during processing and is often quantified by determining temperature and pressure responses, mass flow, and energy consumption.

Feed ingredients for pellet feed preparation

- Rice bran
- Fish meal
- Ground nut Oil cake
- Topica flour
- Vitamins
- Minerals
- Antioxidants
- Immunostimulants
- Colouring Agents

Examples for feed preparation calculation

Using rice bran (protein 9%) and ground nut oil cake (protein 45%) a fish diet with 27% protein can be prepared as follows. A square is constructed and the two ingredients are put on the two left corners along with the protein content of each. The desired protein level of the feed is placed in the middle of the square. Next, the protein level of the feed is subtracted from that of the ingredients and the answer is placed in the opposite corner.



Now the figures on the right side corner of the square are added i.e.18+18=36

Then the % of rice bran to be added in the feed= 18/36 x 100 = 50 %

% of Groundnut Oil cake = 18/36 x 100 = 50 %

To make 1 kg feed, 500g rice bran and 500g groundnut oil cake should be added.

Flow chart for preparation of dry feed

Feed ingredients
↓
Sieved through 300 micron mesh
↓
Mixing
↓
Addition of water 30 – 35%
↓
Dough
↓
Cooking for 15 min in pressure cooker
↓
Cooled
↓
Oil + Vitamin + Antioxidant + growth promotion + Antibiotic + colouring agent sprayed over the feed.
↓
Remixing
↓
Pressed through hand pelletiser (2mm)
↓
Drying

Feeding Techniques

Floating feeds allow observation of the feeding response of the fishes. Because it takes about 24 h for high quality floating pellets to disintegrate, fish may be fed once daily in the proper amount, but twice daily feedings are better. Sinking pellets can be used but extra care must be taken to ensure that they are not wasted. Sinking pellets disintegrate quickly in water. More than one feeding is needed each day. Fish of less than 25 g should be fed at least three times a day.

Sinking pellets may be,

- Slowly fed by hand which allowing time for the fish to eat the feed before it sinks
- Placed in shallow submerged trays
- Placed in demand feeders

Feeding slowly by hand is inefficient. Use of a tray allows quick placement of feed onto the tray, but multiple daily feedings are still required. The correct amount of feed must be weighed daily. Feeding rate tables or programs are required to make periodic increments in the daily ration. Feeding adjustments can be made daily, weekly or every two weeks. The fish should be sampled every four to six weeks to determine their average weight and the correct feeding rate for calculating adjustments in the daily ration. Adjustments can be made between sampling periods by estimating fish growth based on an assumed feed conversion ratio.

Recommended daily feeding rates, expressed as percentage of body weight for fishes of different sizes

Sl. No	Average Body Weight	Feeding rate (% of body weight)	Culture Phase
1	1-5	8	Nursery Rearing
2	6-10	6	
3	10-15	5.5	
4	15-20	4	
5	20-50	4.0-2.5	
6	50-100	2.5-1.7	Grow out Rearing
7	100-200	1.7-1.3	
8	200-300	1.3-1.0	
9	300-500	1.0-0.9	
10	500-700	0.9-0.8	
11	>700	0.8-0.6	

Feeding rate tables serve as guides for estimating the optimum daily ration, but they are not always accurate under a wide range of conditions, such as fluctuating temperatures or dissolved oxygen. Demand feeders can be used to eliminate the work (feed weighing, fish sampling, and calculations) and uncertainty of feeding rate schedules by letting the fish feed themselves. Fish quickly learn that feed is released when they hit a rod that extends from the funnel into the water. Demand feeders and feeding rate schedules produce comparable growth and feed conversion, but demand feeders reduce labour by nearly 90 percent. Feeding rate schedules may still be used with demand feeders by adding a computed amount of feed daily instead of refilling the feeder whenever it is nearly empty. With high quality feeds, good growing conditions and effective feeding practices, feed conversion ratios as low as 1:3 have been obtained. Generally, feed conversion ratios will range from 1.3 to 1.5 kgs of feed per 1kg of fish.

RECENT ADVANCES IN DIAGNOSIS AND MANAGEMENT MEASURES OF FISH AND SHELLFISH DISEASES

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I. Introduction

Aquaculture development is currently moving towards increasing the commercialization and intensification of aquatic production. In India, aquaculture encompasses a diverse range of fishes and shellfish, including Indian major carps, minor carps, catfishes, barbs, tilapia, climbing perch, murrel, pacific white shrimp, black tiger shrimp etc. Diseases and epizootics are to be hampered for increasing production through the development of the aquaculture industry. Several factors are involved in the development of disease problems that include intensification of fish farming practices, the introduction of new species, lack of good quality fish/shrimp seed, misapprehension and misuse of specific pathogen-free stocks, unawareness of emerging and reemerging diseases among the fish farmers, poor availability of diagnostic facilities, lack of infrastructure facilities of the farm, lack of effective biosecurity measures, lack of preventive measures for major pathogens, bad weather condition etc. (Sivasankar *et al*., 2017; Chadha *et al*., 2021). More particularly, the intensification of aquaculture has increased productivity significantly while concurrently accompanied by several infectious diseases (John *et al*., 2023). Disease control in aquaculture is a challenging task because prevention tools are scarce or nonexistent and control strategies are difficult to execute. Besides, many novels, transboundary fish and shellfish diseases have currently been identified and reported in various regions of India and the world.

Thus, contrasting terrestrial counterparts, health management in aquatic animals requires more attention and care for monitoring and managing their health (Sivasankar *et al*., 2017; John *et al*., 2023). Most fish diseases can be controlled by proper scientific management through appropriate biosecurity, nutritional adequacy, prophylactics, water and sediment quality control, adequate aeration, checking, and controlling input quality including fish seed, feed and chemicals, and constant monitoring through sampling (John *et al*., 2023). In India, National Surveillance Programme for Aquatic Animal Disease is being functioned by the Department of Animal Husbandry, Dairying and Fisheries Government of India through the PMMSY scheme as it is essential for earlier detection of disease, thereby minimizing their impact.

Table 1. Important diseases of fish and shellfish in Indian aquaculture

Diseases	Causative agent	Clinical signs and gross pathology
Fish diseases		
Argulosis	*Argulus* sp. (fish louse)	The affected exhibit flashing or scratching, violent erratic swimming, loss of appetite, lethargy and denser shoaling. Fish usually develop red spots or hemorrhagic lesion
Lernaeosis	*Lernaea* sp., (anchorworms)	Fish usually develop localized redness, inflammation on the body, breathing problems and lethargy. Erythomatous or hemorrhagic lesions occur on infected parts of fish body and swelling can be observed in area around the site of attachment of the parasite.
Dactylogyrosis	*Dactylogyrus* sp (gillworms)	Infected fish exhibit signs of irritation like rubbing at the corners or bottom of the pond or tank, flashing and violent swimming, color changes with increased mucus production, swelling of gill, and lamellae fusion with excess mucus production. Fish may show erosion in gills, fins and skin.
Myxosporidiosis	Myxozoan parasite	Diseased fish exhibit lethargic, loss of appetite, stunted growth, emaciation, increased respiratory movements, and frequently gulping air. Gills are covered with large, white, opaque parasite cysts.
Ichthyophthiriosis	*Ichthyophthirius multifiliis*	Fish may show signs of irritation by rubbing at the corners and bottom of the tank or pond, flashing and violent swimming, mucus secretion, skin sloughing and lethargy. White spot may be observed on the skin.
Infection with Aphanomyces	*Aphanomyces invadans*	Infected fish usually develop red spot or small to large ulcerative lesions on the body surface, head, operculum, or caudal peduncle. Large red or grey shallow ulcer, often with a brown necrosis.
Saprolegniasis	*Saprolegnia* sp.	Cotton wool-like tufts on the integument and gills of the fish which may extent over the entire body surface. Lethargy and loss of equilibrium, impaired osmoregulation and respiratory difficulties.

Motile aeromonad septicemia	*Aeromonas* sp.	Loss of appetite, lethargy, epidermal lesion, exophthalmia, hemorrhages and protrusion of scales. The internal lesions include pale liver and gill, ascites, swollen kidney and spleen, flaccid hyperemic intestine and fin & tail rot.
Edwardsiellosis	*Edwardsiella* sp.	Cutaneous lesion, abscesses, distended abdomen, swelling and bleeding of anus, depigmentation, hemorrhages on the ventral part of the body. Fish shows signs of pale gills, tumefaction of the eye, excess mucus secretion, scale erosion, ulcers, spiraling movement and mortality with flared opercula and a gape mouth.
Columnaris disease	*Flavobacterium columnare*	Listlessness, lethargy, inappetence, swimming near the water surface and increased operculur movement. The skin lesion begin as areas of discoloration, primarily at the base of the dorsal fin and spread to form a pale white band that extends laterally and encircles the body to form a characteristic pale white, "saddleback" lesion. In the gills, yellowish-white spots on the tip of the primary lamellae.
Tilapia lake virus disease	TiLV	Lethargy, anorexia, abnormal swimming behavior, skin erosions, protrusion and loss of scales, discoloration, gill pallor, abdominal distension, fluid in the abdominal cavity, pale liver, enlarges gallbladder and spleen along with fluid-filled intestines.
Viral encephalopathy and retinopathy	NNV	Abnormal swimming behavior, uncoordinated darting, belly-up at rest, swim bladder hyperinflation, anorexia, dark or pale colour according to species.
Goldfish haematopoeitic necrosis disease	GHNV	Lethargic behavior, gasping at the surface with erratic swimming, laying at the tank bottom before death, enophthalmos, pale gills, patches of necrotic tissues on the gills and mortality.
Koi sleepy disease	KSDV	Skin haemorrhages with oedema of the underlying tissues, enophthalmos, pale swollen gills, lethargy and unresponsiveness. The affected fish will lie motionless, sometimes on their side, on the bottom of the tank or pond for long periods, as if sleeping. When disturbed by physical stimulation, the fish will swim for a short time and then resume their inactive state on the bottom

		of the pond. Diseased juvenile koi tend to congregate at the surface or around the margins of the pond.
Red sea bream iridoviral disease	RBIV	Lethargic, severe anaemia, patechiae in the gills and enlargement of the spleen. Diseased fish may swim inactively and show obvious operculum movements. Gross lesions include darkened body colour, pale gills and enlarged spleen and morality.
Shrimp diseases		
Hepatopancreatic microsporidiosis	EHP	EHP does not cause mortality; however, it is associated with severe growth retardation in affected shrimps. The infected shrimp post larvae grow at normal rate during first 25 days; however, thereafter, the infected shrimp exhibit reduction in feed consumption and discolored hepatopancreas. The growth of infected shrimps is only 10-40% of non-infected shrimps. EHP has also been reported from shrimp exhibiting white feces syndrome
White spot disease	WSSV	White spots embedded within the exoskeleton of shrimps, ranging from barely visible to 3 mm in diameter. High degrees of colour variation with a predominance of reddish or pinkish discolored shrimp. The shrimps may gather around the edges of ponds/tanks at the water surface, and there is rapid reduction in food consumption. A very high mortality rate can be expected with a few hours to a few days of the onset of these signs
Infectious hypodermal and haematopoietic necrosis	IHHNV	Cuticular deformities, specifically a deformed rostrum bent to the left or right, called runt deformity syndrome (RDS), a deformed sixth abdominal segment, wrinkled antennal flagella, cuticular roughness and 'bubble heads'. Populations of juvenile shrimp with RDS display disparate growth with a wide distribution of sizes and many smaller than expected ('runted') shrimp
Infectious myonecrosis	IMNV	Typically, severely affected shrimp exhibit lethargy, shrimp in the acute phase of IMN disease present focal to extensive white necrotic areas in muscles, especially in the distal abdominal

		segments and tail fan, which can become necrotic and reddened in some individual shrimp. The paired lymphoid organs may be hypertrophied up to 3 -4 times their normal size
Hepatopancreatic parvovirus disease	HPV	The disease is linked to chronic mortalities during the early larval or postlarval stages and it may result in stunted growth during the early juvenile stages. The effect of HPV infection on adult may compromise their survival if the infection is severe.
White tail disease	MrNV	Infected PL become opaque and develop a whitish appearance, particularly in the abdominal region. The whitish discoloration appears first in the second or third abdominal segment and gradually diffuses both anteriorly and posteriorly. In severe cases, degeneration of telson and uproads may occur. The mortality reaches a maximum in about 5 days after the appearance of whitish coloration. The infected PL show progressive weakening of their feeding and swimming ability.
Spherical baculovirosis	MBV	Lethargy in severely affected PLs. Protozoea, Mysis and early PL stages with severe infections may present a whitish midgut. Juveniles and adults present no gross signs of diagnostic value, nor do larvae with less severe infections.

Under this surveillance programme, many aquaculture pathologists throughout India are working together, who have acquired skills in fish and shellfish disease diagnosis and health management. This article provides a thorough insight into advances in fish and shellfish disease diagnostic techniques and management methods.

II. Diagnostic techniques for fish and shellfish diseases

1. Image processing technology

Significant progress has been achieved in fish disease diagnosis through the utilization of expert systems, which have long been the primary approach for traditional fish disease diagnosis methods (Wagner, 2017). Nevertheless, the accuracy and efficiency of fish disease diagnosis heavily rely on the expertise and experience of the professionals involved (Park *et al*., 2007). As image-processing technology continues to advance at a rapid pace, various features extracted from disease images, including texture, shape, and colour, hold promising potential as indicators for fish disease diagnosis (Lou *et al*., 2010). The utilization of camera images, microscopic images, spectral images, ultrasound images, and fluorescence images has demonstrated feasibility in fish disease diagnosis. By combining image-processing technology with computer vision, it becomes possible to achieve non-destructive, automatic, rapid, and real-time diagnosis of fish diseases. This approach offers advantages such as low-cost implementation, simplicity of operation, high sustainability, and minimal impact on water bodies in terms of pollution (Hu *et al*., 2012). Image-processing technology encompasses several key steps, including image acquisition, image pre-processing, image segmentation, feature extraction, target detection and recognition, and classification. These sequential processes form the core components of utilizing images for disease diagnosis in fish.

Infectious diseases are the major constraints to aquaculture and the limiting factor for the economic and socioeconomic development of fish farmers in India. Fish diseases can arise from various sources, including not only common pathogens such as parasites, fungi, bacteria, and viruses (Table 1) but also certain physical phenomena and chemical agents that have the potential to induce fish diseases. Existing studies have predominantly focused on detecting hosts through surface changes in fish, while pathogen detection relies on identifying internal tissue alterations such as deformities, necrosis, decay, and bleeding. However, pathogen detection methods typically offer only a rough indication of pathogen presence. Given the diverse range of pathogens affecting fish, accurate identification necessitates biochemical pathogen-detection techniques. High-quality images play a vital role in precise disease detection. Initially, image-processing technology enhances the quality of fish images, followed by their segmentation, detection, and identification using these improved images. Ultimately, fish diseases are diagnosed based on fish classification, leveraging the comprehensive information obtained through this process.

2. Phage Display

The phage display method was initially introduced by G. P. Smith in 1985 as a means to express cloned antigens on the surface of viruses (Smith, 1985). Phages, which are viruses capable of utilizing bacterial cells as replication factories and presenting peptides or proteins on their surfaces, employ a technique known as phase display. The combinatorial nature of phage display technology has garnered significant attention as a promising avenue for the future of drug discovery. The application of phages in controlling bacterial diseases in aquaculture has shown promising results in finfish and prawns, highlighting their therapeutic potential (Karunasagar *et al*., 2007). Phage display libraries have been successfully developed for several significant pathogens, including *Myxobolus rotundus*, yellow head virus (YHV), White spot syndrome virus (WSSV), Infectious hematopoietic necrosis virus (IHNV), and spring viraemia of carp virus (SVCV). Phage display is an effective in vitro selection method that enables the quick identification of proteins possessing desired attributes, such as enhanced affinity, specificity, stability, and novel enzymatic activity. Its efficacy stems from the linkage between the displayed protein of interest on the phage surface and the encoding DNA packaged within the phage particle, establishing a phenotype-to-genotype connection. This feature facilitates the selective enrichment of library pools and enables high-throughput screening of resulting clones, thus maximizing the potential of phage display. Phage display serves as an exceptional technological platform for engineering antibodies or proteins with improved properties due to its high-throughput nature, rapidity, and user-friendly characteristics.

3. SELEX aptamers

Systematic evolution of ligands by exponential enrichment (SELEX), also known as in vitro selection or in vitro evolution, along with SAAB (selected and amplified binding site) and CASting (cyclic amplification and selection of targets), represents a novel combinatorial chemistry technology that emerged in the early 1990s (Blackwell & Weintraub, 1990). The technique was first developed by was first developed by Tuerk and Gold (Tuerk & Gold, 1990), and Ellington and Szostak (Ellington & Szostak, 1990), separately. Thus far, a multitude of aptamers have been generated, targeting diverse entities including amino acids, proteins, small metal ions, organic molecules, bacteria, viruses, whole cells, and animals, amounting to thousands of aptamers in total. Aptamers, which are single-stranded DNAs or RNAs, can be obtained through the SELEX method, wherein a library containing random sequences is subjected to selection. Monitoring the enrichment progress of aptamer candidates remains a crucial step in the SELEX process to this day. The conformational changes observed in an aptamer upon binding to a target within a gel can serve as an indicator of its binding status (Liu *et al*., 2020). SELEX aptamers have been successfully developed for *Vibrio alginolyticus*, a significant pathogenic bacterium affecting fish and shellfish (Zheng *et al*., 2015), as well as for Singapore grouper iridovirus, a major viral pathogen that inflicts substantial economic losses on the grouper aquaculture industry (Li *et al*., 2014).

4. Luminex assays

The Luminex system is an advanced platform that uses microspheres to perform multiplexed analysis, allowing for the simultaneous detection and reporting of up to 100 different reactions in a single vessel (Dunbar, 2006). This innovative technology shows great potential for the future development of disease screening programs in aquaculture. In a recent study, Hoare and his colleagues successfully utilized the Luminex bead array technology to detect and quantify the infectious salmon anaemia virus in plasma samples from fish (Hoare *et al*., 2016).

Although the potential of utilizing the Luminex system as an alternative diagnostic tool in aquaculture exists, its development is still underway. This advanced technology can employ up to 100 fluorescent bead sets, each uniquely distinguishable by its fluorescent emission when stimulated by a laser. These bead sets contain different ratios of two distinct fluorophores, offering the opportunity for enhanced detection compared to conventional methods like ELISA and RT-qPCR.

In this assay, individual bead sets are conjugated with specific proteins, peptides, oligonucleotides, or antibodies, such as anti-ISAV monoclonal antibodies (mAb). These coupled beads are then incubated with a sample, such as plasma from ISAV-infected fish, in a 96-well ELISA plate. Following that, a biotinylated antibody, such as a different anti-ISA mAb, is added and detected using streptavidin-phycoerythrin as the reporter. The assay is read on a Bio-Plex reader equipped with a dual laser system. The first laser excites the fluorophores within the beads (classification laser), while the second laser detects the fluorescent emission from the antibodies bound to the beads (detection/reporter laser). As each bead passes through the reader, its internal fluorescent emission identifies the attached antibody and the fluorescent emission from the detection antibody on the bead's surface allows the quantification of the bound target. The mean fluorescence intensity (MFI) of the detection fluorescent antibody is measured for 100 beads from each bead set.

5. Polymerase Chain Reaction (PCR)

Polymerase chain reaction (PCR) is a powerful technique for amplifying specific DNA regions using primers and DNA polymerase. PCR allows for a significant increase in the targeted

DNA section and can be detected using gel electrophoresis. Amplified regions typically range from 150 to 3,000 base pairs. Primer design is crucial for sensitivity and specificity, requiring an optimal length to prevent nonspecific annealing. The PCR reaction involves template DNA, primers, polymerase enzyme, and nucleotides. Each thermocycling round denatures the template DNA, allows primer annealing, and facilitates polymerase-mediated nucleotide addition, resulting in new copies of the target region. Reverse transcriptase PCR (RT-PCR) detects specific mRNA and quantifies gene expression levels, even from small samples or single cells. Real-time RT-PCR, with its ability to detect changes in gene expression and validate array analyses, has gained widespread adoption. Its sensitivity and specificity make it ideal for surveillance and monitoring of hidden infections. Conserved regions in prokaryotic rRNA genes can be exploited to identify or amplify these genes, followed by analysis of more variable regions or spacers to detect bacteria that are challenging to culture.

6. Multiplex PCR

New advancements in PCR technology, such as multiplex PCR, enable the detection of multiple pathogens simultaneously, enhancing the efficiency and cost-effectiveness of this method. Multiplex PCR amplifies more than one target sequence by incorporating multiple primer pairs in a single reaction. This approach saves time and effort in the laboratory without compromising the usefulness of the test. Multiplex PCR has found success in various areas of nucleic acid diagnostics, including gene deletion analysis, quantitative analysis, and RNA detection. In the field of infectious diseases, it has proven valuable for identifying viruses, bacteria, fungi, and parasites.

7. Restriction Fragment Length Polymorphism (RFLP)

RFLP is a technique that distinguishes organisms by analyzing patterns resulting from DNA cleavage. Differences in the distance between cleavage sites of a specific restriction enzyme led to variations in fragment lengths. By comparing these patterns, species and strains can be differentiated. DNA isolation for RFLP analysis is time-consuming, but PCR allows for the amplification of small DNA amounts in 2-3 hours, enabling faster analysis of more samples.

8. Amplified Fragment Length Polymorphism (AFLP)

AFLP is a rapid PCR-based technique used for typing prokaryotes and eukaryotes. It amplifies selective markers in the genomic restriction fragments, making it a quick and easy tool for strain identification in various fields. AFLP analysis involves ligation of adapters to genomic restriction fragments, followed by PCR amplification with adapter-specific primers. Only a small amount of purified genomic DNA is required, which is digested with two restriction enzymes. Oligonucleotide adapters are designed to prevent restoration of the initial restriction site after ligation, allowing simultaneous restriction and ligation while cleaving religated fragments. The resulting fragments undergo two subsequent PCR amplifications using adapter-specific primers. Fluorescently labeled primers have replaced radioactive ones for fragment detection. In small bacterial and fungal genomes, a single PCR amplification with selective nucleotides on both primers is sufficient. AFLP offers rapid, reproducible, and highly discriminatory typing for various applications in agriculture, botany, microbiology, and animal breeding.

9. Random Amplified Polymorphic DNA (RAPD)

RAPD is a technique applied to the study of various organisms, including the crayfish plague fungus and fish pathogens. RAPD involves low-stringency polymerase chain reactions with a single primer, resulting in different-sized fragments due to random primer binding on nonidentical DNA samples. It has been utilized to group different isolates of the fungus and conduct epidemiological investigations. RAPD has also been used to examine a species of Aphanomyces causing fish losses in Asia. While RAPD has issues with reproducibility and contamination risks, it can be valuable as an initial step in developing specific primers or probes and has been employed in bacterial studies.

10. In situ hybridization

In situ hybridization techniques, including in situ PCR and fluorescence in situ hybridization (FISH), have significantly contributed to research and clinical practice. They have enhanced our understanding of infectious and neoplastic diseases, improved disease diagnosis, and provided detailed information about gene expression in specific cells while preserving anatomical context. However, challenges such as low detection sensitivity, poor reproducibility, and high background interference have limited their utility. To address these limitations, researchers have developed a specific fluorescent detection method for gene expression using in situ RT-PCR, which allows for low-level gene expression detection with minimal background interference. This method finds application in various areas such as virus detection, tumor cell characterization, genetic mutation diagnosis, and gene expression analysis in tissues. FISH, on the other hand, involves labeling cells or chromosomes based on their nucleic acid sequences. It utilizes fluorescently labeled DNA or RNA probes to hybridize with target nucleic acids, particularly ribosomes in microbiology. This results in labeling of cells containing complementary RNA sequences, enabling visualization using flow cytometry or fluorescence microscopy.

11. DNA Microarrays

DNA microarrays are a versatile tool for detecting unique DNA or RNA sequences. They can be used in different ways, such as fluorescent labeling of all DNA sequences in a sample or competitive hybridization. In competitive hybridization, the test sample competes with a fluorescently labeled competitor oligonucleotide for binding to a tethered oligonucleotide on the microarray. By analyzing the fluorescence signals using computer programs, the presence or absence of specific DNA sequences can be determined.

Compared to traditional nucleic acid hybridization methods, microarrays offer several advantages, including high density, sensitivity, rapid detection, lower cost, automation, and low background levels. They are particularly useful for large-scale diagnostic testing and simultaneous detection of multiple sequences. Microarrays can be designed to include oligonucleotide probes complementary to various pathogens, allowing the identification of fish pathogens in fish populations. Furthermore, microarrays can be used to assay gene expression, providing insights into pathogenicity and gene presence in pathogens.

Although the setup cost for DNA microarrays is high, once the equipment is available and microarrays are prepared, the cost per sample analyzed becomes low. Additionally, the analysis time is relatively short. In the future, DNA microarray technology holds promise for diagnosing fish diseases, especially during the asymptomatic period. Overall, DNA microarrays offer a powerful and efficient approach for detecting and studying DNA or RNA sequences, enabling a wide range of applications in various fields, including pathogen identification and gene expression analysis.

12. Loop-mediated isothermal amplification (LAMP)

LAMP is a rapid and efficient nucleic acid amplification method that can amplify DNA or RNA sequences under isothermal conditions. This method utilizes a DNA polymerase with high strand displacement activity and a set of four specially designed primers to achieve high specificity and efficiency. LAMP can amplify target DNA or RNA sequences with high sensitivity and is particularly useful for point-of-care testing and field-level applications.

The LAMP reaction involves a series of steps where all four primers are initially involved, followed by cycling reactions using only the inner primers. The reaction starts with an inner primer that recognizes specific sequences of the target DNA or RNA, leading to the release of single-stranded DNA. This single-stranded DNA serves as a template for further DNA synthesis using the second set of inner and outer primers, resulting in the formation of stem-loop DNA structures. The cycling process continues, leading to the accumulation of a large number of copies of the target sequence.

The visualization of amplified products in LAMP can be done using various methods. Agarose gel electrophoresis is commonly used, where the gel is stained with intercalating dyes to visualize the products as a smear and bands of various lengths. Alternatively, intercalating dyes can be added directly to the reaction tube, allowing visualization of the product under a UV transilluminator. The presence or absence of a white precipitate (magnesium pyrophosphate) can also indicate successful amplification. Additionally, real-time colorimetric estimation of the turbidity of the reaction mixture can provide a visual indication of the amplified product.

LAMP offers several advantages, including high amplification efficiency, high sensitivity, and simplicity of the reaction setup. It can detect a few copies of the target sequence and is not significantly influenced by the presence of non-target DNA. LAMP is highly specific due to the use of multiple primers targeting different sequences. It can be performed using basic laboratory equipment like a water bath or heat block. Furthermore, LAMP can be adapted for RNA amplification by incorporating reverse transcription. However, LAMP has some limitations. The high amplification of the target sequence at the final stage makes it susceptible to contamination in subsequent amplifications. Multiplexing, which is the simultaneous amplification of multiple target sequences, is not easily achievable with LAMP.

In summary, LAMP is a powerful nucleic acid amplification method that offers rapid, specific, and efficient amplification of DNA or RNA sequences under isothermal conditions. Its simplicity and high sensitivity make it suitable for various applications, particularly in resource-limited settings and point-of-care testing.

13. Immunological diagnosis

Immunological diagnostics rely on the highly specific and sensitive reactions between antigens and antibodies. These methods are used for qualitative and quantitative estimation of pathogens and protective antibodies. Immunodiagnostic techniques, particularly antibody-based methods, play a crucial role in disease diagnosis in aquaculture. They can detect sub-clinical/latent/carrier states of infection and distinguish antigenic differences. Monoclonal antibody-based techniques have increased accuracy and facilitated the study of disease pathogenesis. Several immunodiagnostic tests are available, including:

Agar Gel Precipitation Test: Antigen and antibody are placed in wells on agar plates, and the formation of a visible precipitin line indicates a specific reaction.

Agglutination Test: Used to identify unknown antigens by mixing blood with a known antibody. Agglutination indicates the presence of the antigen. It is employed in tissue matching, blood grouping, and diagnosis.

ELISA (Enzyme-Linked Immunosorbent Assay): Determines the presence and quantity of a specific protein in a sample. It can quantify antibodies or measure protein bound by an antibody. The sample is incubated in wells coated with a protein that binds the antibody of interest. Enzyme-labeled secondary antibodies generate a colored product, and the optical density reflects the amount of bound antibodies.

DOT ELISA: Utilizes two antibodies that sandwich the antigen, with one antibody immobilized on a solid support and the other linked to an enzyme. The enzyme activity produces a colored spot that is proportional to the antigen concentration.

Latex Agglutination Test: Detects specific antibodies or antigens in bodily fluids by mixing them with sensitized latex particles. Agglutination is visible as clumping of the latex particles.

Fluorescent Antibody Test: Uses fluorescently labeled antibodies to detect microorganisms. The presence of antigens is visualized through fluorescent signals, indicating the presence of the microorganism.

Immunodiagnostic techniques provide rapid, specific, and sensitive results, enabling the detection and quantification of pathogens and protective antibodies in various samples.

14. Fish Cell Lines

Fish cell lines play a crucial role in the aquaculture industry, particularly in the isolation and identification of viruses that cause diseases in commercially important fish species. These cell lines are essential for precise diagnostics, prophylactics, and quarantine programs to ensure virus-free fish stocks. They also find applications in cytogenetics, transgenics, toxicology, in vitro studies of cellular processes, and comparative immunology. However, there is limited availability of fish cell lines, especially for tropical species. Most established cell lines are from Asian freshwater, marine, and brackish water fishes. Currently, approximately 283 cell lines have been established worldwide, but there is a lack of appropriate cell lines for many farmed marine food fish and ornamental fish. This limitation hampers the development of preventive strategies and health certification for viral diseases in fish.

15. Bio-barcode Assay

The bio-barcode assay is a highly sensitive technique used for detecting nucleic acid and protein targets. It employs magnetic microparticle probes with specific antibodies and DNA-encoded nanoparticle probes. The DNA barcode serves as a reporter, allowing for signal amplification and direct detection of DNA with remarkable sensitivity. For protein detection, the assay achieves exceptional sensitivity, surpassing traditional ELISA tests by a millionfold. The barcode strands can be identified using scanometric detection or in situ methods, and PCR or Real-Time PCR can also be utilized for detection and quantification. The bio-barcode assay has demonstrated high efficiency in the early detection of human diseases, animal viruses, and aquatic toxins. With its original concept and potential as an alternative to PCR and ELISA, this technique holds promise as an early disease detection and diagnostic tool in aquaculture

16. Lateral Flow Kits

Lateral flow kits offer a fast and sensitive method for pathogen detection using immunochromatography. Their simplicity and specificity make them useful for on-site testing, such as in pond settings. Commercial ISAV kits, for example, demonstrate sensitivity comparable to one-step PCR. This technology provides advantages over traditional immune assays: it is user-friendly, quick (<10 mins), cost-effective, and does not require skilled personnel or expensive equipment.

17. Bluspot Technology

Bluspot technology is a rapid assay where the sample is filtered through a membrane coated with a specific monoclonal antibody (MAb) targeting the pathogen. This concentration step enhances the sensitivity of the reaction. The antigen-antibody complexes formed are detected using an enzyme-labeled secondary antibody. A positive reaction is indicated by the development of color upon enzyme-substrate reaction. The bluspot test delivers results in just 5 minutes, making it highly rapid and efficient.

III. Management measures in aquatic animal health

1. Vaccines

Fish health management, including good hygiene and minimizing stress, is crucial for preventing infectious diseases and ensuring the effectiveness of vaccines. Vaccination exposes the host organism to organic molecules that elicit a specific immune response, providing better protection against subsequent infections from specific pathogens. To address concerns about pollution and antibiotic resistance, preventive measures such as optimal husbandry, biological control methods like vaccination needs to be developed. Vaccination has proven to be cost-effective and has reduced reliance on antibiotics. A wide range of commercial vaccines exists for bacterial and viral pathogens, with ongoing development of new vaccines. Traditionally, vaccines are derived from inactivated pathogens cultured and presented to the host. Many vaccines contain inactivated antigens from over ten bacterial pathogens and five viral pathogens. Molecular-based vaccine production heavily relies on biotechnological tools and is primarily carried out in developed countries. Most available vaccines are inactivated or killed disease agents, while live attenuated vaccines have been developed for viruses, albeit with a risk of reverting to a virulent state. Other vaccine types include recombinant vaccines like DNA vaccines and subunit vaccines, developed for specific pathogens such as IPNV and IHNV.

Live attenuated vaccines are a type of vaccine that is genetically modified to decrease its virulence while remaining live. They induce an immune response in the host for a short period. These vaccines have significant importance in aquaculture and have been used since the 1990s. Attenuated vaccines stimulate cellular, humoral, and mucosal immunity, resembling a controlled infection model. Another approach in aquaculture is the use of alive feeds bio-encapsulated with vaccines. This method involves incorporating vaccine suspension into live feeds such as Artemia, copepods and rotifers, which are then fed to fish. The bio-encapsulated feed releases the vaccine in the fish's digestive tract, reducing fish handling and stress while enabling mass immunization. To enhance vaccine delivery, researchers are exploring the use of nanoparticles as adjuvants and efficient delivery systems. Nanoparticles can be taken up by cells through endocytosis, enhancing antigen uptake and presentation.

2. Immunostimulants and phytotherapy

Immunostimulants are synthetic or biological-based substances which stimulate the immune system to nurture innate and specific immunity for disease control. Astaxanthin, chitosan, fucoidan, 1-3 glucan, herbal extracts, laminaria, lipopolysaccharides, peptidoglycans, saponins, vitamin C etc. form the major immunostimulant products in aquaculture to prevent fish diseases. In addition, a large number of herbal formulations can also be used to control fish and shellfish diseases effectively.

3. Surface display technique

Vaccination stimulates specific immunity, eliminating microbes, neutralizing toxins, and preventing further invasion. Recombinant DNA technology is widely used for producing cost-effective protein vaccines in the aquaculture industry. These vaccines offer safety and efficiency compared to live or attenuated vaccines and provide an alternative to formalin-killed whole-cell vaccines. Microbial cell surface displays have various applications, including vaccine development. Displaying virulence factors on the cell surface of hosts like *Saccharomyces cerevisiae* enables the production of live vaccines efficiently. This approach holds promise for combating bacterial and viral diseases in fish, offering a potential solution for the aquaculture industry.

4. Egg Yolk Antibodies (IgY)

Chicken immunization offers advantages over other mammals. Antibody productivity from chicken yolk is significantly higher than that from rabbits. The collection of eggs is less invasive compared to blood collection. Chickens require less antigen to generate an immune response, and their antibodies recognize different epitopes than mammalian antibodies, resulting in a unique antibody repertoire. Egg yolk contains a single class of antibody (IgY) that can be easily isolated. IgY antibodies have applications in immunodiagnostic kits and passive immunotherapy against diseases.

In various studies, IgY antibodies have shown effectiveness in protecting eels from *E. tarda* infection, reducing mortality and infection rates in rainbow trout challenged with *Y. ruckeri*, and providing protection against *Vibrio anguillarum* in rainbow trout. IgY antibodies against White Spot Syndrome Virus (WSSV) have demonstrated passive protection in shrimp and crayfish, administered through immersion or feed incorporation. Chicken antibodies have proven efficient in diagnosing and preventing viral infections in shrimp and crayfish, as well as combating fish pathogens such as *E. tarda, Y. ruckeri,* and *Vibrio* spp.

5. Prebiotics

Prebiotics is typically carbohydrates derived from plant or yeast origin. Among many food ingredients known the inulin, fructooligosaccharide (FOS), mannan oligosaccharide (MOS) and isomalto oligosaccharide (IMO) are commonly used prebiotics. Prebiotics is typically carbohydrates derived from plant or yeast origin (Sivasankar *et al*., 2017). Non-digestible food constituents called mannan-oligosaccharides (MOS), derived from yeast cell wall components, have positive effects on intestinal health in fish. MOS stimulates the growth of beneficial bacteria like lactobacillus while reducing the presence of harmful bacteria in fish farms. Studies have shown that dietary supplementation with MOS enhances growth, hemolytic activity, and phagocytic activity, leading to improved fish survival during challenges with pathogens such as *V. anguillarum*. Additionally, rainbow trout fed with MOS-enriched diets exhibit significant improvements in growth performance, antibody titer, and lysozyme activity.

6. Probiotics

Probiotics are microorganisms or their components that provide beneficial effects to the host or its environment by modifying the microbial community associated with the host, ensuring improved use of the feed or enhancing its nutritional value, enhancing the host response towards disease, or improving the quality of its ambient environment (Verschuere *et al*., 2000; Michael *et al*., 2014; Sivasankar *et al*., 2017). Many probiotics, including those of host origin, have been studied and applied in fish. The selection of probiotics involves in vitro tests to assess their ability to inhibit pathogenic bacteria, such as the agar well diffusion test. In vivo challenge tests are also conducted to evaluate their protective effects on animals. Once officially registered and economically evaluated, probiotics can be approved as commercial products. Probiotics can be administered in dry form as food supplementation or added to water, or in liquid form that is ready for use. The liquid form can be added directly or mixed with food, offering faster effects compared to the dry form.

7. Synbiotic

The combination of prebiotics and probiotics is known as synbiotics, which enhances the survival and growth of beneficial bacteria in the gastrointestinal tract. When administered individually, *Enterococcus faecalis* or mannan-oligosaccharides (MOS) in salmonid fish have shown positive effects on immune response and survival during challenges with *V. anguillarum*. However, the combined synbiotic feeding of *E. faecalis* and MOS has demonstrated significantly improved results compared to using either probiotics or prebiotics alone.

8. Antagonist of quorum sensing

Quorum sensing (QS) is a bacterial communication system that regulates gene expression. Probiotics can disrupt QS, offering potential anti-infective benefits in aquaculture. Halogenated furanones derived from the marine red alga *Delisea pulchra* act as QS antagonists, protecting rainbow trout from pathogenic vibrio. *Lactobacillus acidophilus* produces molecules that inhibit the QS of Escherichia coli O157 gene.

9. Bacteriophages therapy

Bacteriophages offer a highly effective biological control method for pathogenic bacteria in aquaculture. They are safe for humans and animals and have various applications in biotechnology and medical sciences, such as disease prevention, treatment, and rapid detection. Bacteriophages are highly specific, targeting only bacterial cells with matching surface receptors. Their use in controlling fish pathogens is particularly advantageous as it does not leave any drug residues. By isolating and identifying specific phages, targeted elimination of pathogens can be achieved, making phage therapy a promising approach in aquaculture disease management.

Determining the appropriate dosage of phages is crucial for effective phage therapy. Studies have reported varying dosages, and it is important to focus on isolating and characterizing phages that have high infectivity at lower doses and a rapid replication rate. Several modes of application for phages in aquaculture have been reported, including oral administration through feed, intramuscular or intraperitoneal administration, anal intubation, immersion, and direct release in the culture system. Each mode of application has its advantages and disadvantages, depending on the nature of the pathogen and the practicality of the administration route. Phage cocktails, which involve the use of multiple phages together or in combination with other therapeutics, such as antibiotics or lysozymes, are also being explored as promising approaches in aquaculture.

IV. Conclusion

Aquaculture has grown to become a major economic and food-producing sector in India and the world. Due to infectious diseases caused by viruses, bacteria, fungi and parasites, the aquaculture business faces a significant problem in a sustainable supply of affordable animal protein in the form of fish. Numerous novel diseases have been discovered in recent years through the advancement of diagnostic tools and the availability of skilled researchers. It is more possible to control infectious diseases by proper scientific management through appropriate biosecurity, nutritional adequacy, prophylactics, water and sediment quality control, adequate aeration, checking, and controlling input quality including fish seed, feed and chemicals, disease surveillance through sampling and reporting. The development of effective health management strategies in the culture of fish and shellfish should be a top priority for successful aquaculture production. Additionally, recent technological advancements in aquaculture for the quick diagnosis and management of pathogens, maintenance of the health status of cultured animals and environment through prevention, as well as treatment, would undoubtedly play a crucial role in achieving the balance required for health management in aquaculture.

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Economics of Fisheries Enterprises and Government Schemes for Fisheries Development

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Introduction

Fisheries play an important role in our national economy in feeding the rising global demand for protein rich food, foreign exchange earnings and in providing employment opportunities to millions of stakeholders especially the marginalized and vulnerable communities of the country. During 2021-22, India has not only become the 2nd largest fish producer accounting to 7.56% of total global production through sustainable utilization of resources but also stood as 4th largest exporter of fish and fisheries products taking Brand India from Local to Global. It contributes to about 1.24% to the country's GVA and over 7.28% to the Agricultural GVA (NFDB, 2023).

Fishery economics is a central component to fishery management, explaining stakeholder behavior as well as the impacts of various management decisions. Foreseeing the immense potential for development of fisheries and for providing focused attention to the sector, the Government has launched many schemes and is being operationalized for the benefit of the fishers and fish farmers' community. Against this background, the information on the economics of various fisheries enterprises and the government schemes related to fisheries sector are detailed in this paper.

Economics of fisheries enterprises

The economic performance of any enterprise is normally estimated with the calculation of costs (capital cost, fixed cost, variable cost and total cost) and returns (total returns and net returns). Capital cost is the summation of the values of all the fixed assets used for taking up the economic activity. Fixed cost is calculated for five components viz., Depreciation, Interest on capital, Repairs and maintenance, Tax and Insurance (ACRONYM – DIRTI-5). Through the estimation of Benefit-cost ratio (BCR), the economic viability of the enterprise will be arrived. If BCR is > 1, it could be inferred that, the business is a profitable venture. Total Income/Returns is estimated by multiplying the total production with the selling price per unit. The difference between the total returns and total cost is net returns. Based on the above, the economics of different fisheries enterprises is given below.

A. COMPOSITE FISH CULTURE

Indicative cost of composite fish culture in a new pond of 01 Acre water spread area (Model Bankable Project)

S. No.	Particulars	Unit	Rate	Amount (Rs.)
A) Capital Cost				
1.	Site Clearance	L.S		5000
2.	Construction of Pond, including digging, bund construction, compaction & consolidation	4500 Cubic Meter	45 per Cubic Meter	20250
3.	Installation of a bore-well with 3 inch diameter delivery pipe and a 3 H.P electric motor	3 H.P		100000
4.	Inlet & Outlet Sluices	L.S		5000
5.	Store room cum Rest room			10000
6.	Nets and other Implements			10000
			Sub Total A	332500
B) Operational / Variable cost				
7.	Lime	200 Kg	15 Per kg	3000
8.	Cow dung	4000 Kg	0.75 Per kg	3000
9.	Urea	120 Kg	16 Per kg	1940
10.	SSP	80 Kg	25 Per kg	2000
11.	Fish seed (Fingerlings)	3000	No 2 Per seed	6000
12.	Floating Pellet feed	600 Kg	35 Per kg	21000
13.	Farm-made supplementary feed	1800 Kg	20 Per kg	36000
14.	Medicine and chemicals	1 L. S	2500	2500
15.	Harvesting expenses	1200 Kg	3 Per kg	3600
16.	Insurance @ 2.5% of the input cost			1886
17.	Miscellaneous cost	1 L. S	1500	1500
			Sub Total B	82426
			Grand Total (A+B)	**415000**

Income - Expenditure Statement

1.	Culture period (Months)	11
2.	Stocking density of seeds (Nos)	3000
3.	Average survival rate of seeds (%)	90
4.	Average annual growth rate of fish (kg) in 1st year	0.75
5.	Average annual growth rate of fish (kg) from 2nd year onwards	0.90
6.	Fish production in 1st year (kg)	2025
7.	Annual fish production from 2nd year onwards (kg)	2430
8.	Farm gate price	100

9.	Gross Annual income in 1st year	202500
10.	Annual Recurring Cost in 1st Year	82500
11.	Annual Net Income in 1st Year	120000
12.	Gross Annual income from 2nd year onwards	243000
13.	Annual Recurring Cost from 2nd year onwards	82500
14.	Annual Net Income from 2nd year onwards	160500
BCR (TR/TC): 2.33		

Source: NABARD

(https://www.nabard.org/info-centre-model-bankable projects.aspx?cid=506&id=24)

B. FABRICATION OF GLASS AQUARIUM TANK

Sl. No.	Particulars	Amount (Rs.)
1.	Glass panels (95×30×45 cm with 6 mm thickness)	700
2.	Squeezing Gum	300
3.	Silicon Gel	50
4.	Rope & Thermocole	50
5.	Hood with lighting facilities	1000
6.	Miscellaneous	100
7.	Total cost per tank	2200
8.	Selling price per tank	2500
9.	Profit per tank	300
BCR (TR/TC): 1.14		

C. ORNAMENTAL FISH CULTURE

Sl. No.	Particulars	Amount (Rs.)
A) Capital cost		
1.	Land (1/2 acre)	1000000
2.	Shed with cement platform (400 sq. m)	480000
3.	Cement tanks (20 nos. @ 5000/tank) 4-5 m dia	100000
4.	Drainage system	15000
5.	Water pumping and pipeline connections	10000
6.	Filtration system	10000
7.	Electrical connections	15000

8.	Aerators	15000
9.	2 Hp pump and accessories	15000
10.	Glass tanks	5000
11.	Plastic tubs / Buckets	5000
12.	Oxygen cylinder and accessories	10000
	Sub Total A	**1680000**
B) Variable cost		
13.	Brooders	
	Live bearers (20 pairs)	1000
	Gold fish (10 pairs)	5000
	Fighter (10 pairs)	2000
	Gourami (10 pairs)	2000
14.	Feed - Dry feed (18 kg/year) & Live feed	36000
15.	Medicines, chemicals and fertilizers	2000
16.	Electricity charges	12000
17.	Labour	60000
18.	Miscellaneous	30000
	Sub Total B	150000
	Grand Total	**1830000**
C) Production		
19.	Live bearers (60000 nos. @ Rs. 3/fish)	180000
20.	Gold fish (40000 nos. @ Rs. 6/fish)	240000
21.	Fighter and Gourami (25000 nos. @ Rs. 5/fish)	125000
	Total Returns / year	545000
	Interest on CC (12%)	201600
	Total cost	351600
	Net returns	**193400**
BCR (TR/TC): 1.55		

D. ORNAMENTAL FISH CULTURE (BACKYARD UNIT)

Sl. No.	Particulars	Amount (Rs.)
A) Capital cost		
1.	Cement tanks (20 nos. @ 500/tank)	10000

2.	Aerator	7000
3.	Pump and other accessories	2500
4.	Glass tanks	500
	Sub Total A	20000
B) Variable cost		
5.	Brooders	3000
6.	Feed	5000
7.	Medicines, Chemicals and Fertilizers	500
8.	Miscellaneous	1000
	Sub Total B	9500
	Grand Total (A+B)	29500
C) Production		
9.	Live bearers (20000 nos. @ Rs. 2/fish)	40000
10.	Gold fish (5000 nos. @ Rs. 5/fish)	25000
11.	Fighter and Gourami (3000 nos. @ Rs. 4/fish)	12000
	Total Returns / year	77000
	Total cost / Year	29500
	Net returns / Year	47500
BCR (TR/TC): 1.55		

E. SHRIMP FARMING (One ha)

Sl. No.	Particulars	Amount (Rs.)
A) Capital cost		
1.	Lease amount	150000
2.	Pond construction	100000
3.	Aerators; (5 Nos.)	300000
4.	Other infrastructure facilities	100000
5.	Generator	350000
	Sub Total A	**1000000**
B) Fixed cost		
6.	Depreciation	100000
7.	Repairs & maintenance	100000
8.	Interest on CC	200000

	Sub Total B	**400000**
C) Variable cost		
9.	Fertilization	50,000
10.	Medicines	100000
11.	Shrimp seed (50000 nos./ha)	400000
12.	Feed	800000
13.	Power	50000
14.	Fuel	100000
15.	Labour	50000
16.	Harvesting	20000
	Sub Total C	1570000
Production/ha		8000 kg
Selling price/kg		Rs. 400
	Total Returns	Rs. 3200000
	Total Cost	Rs. 2400000
	Net Returns	Rs. 800000
BCR (TR/TC): 1.33		

Government schemes

The Government provides utmost care and importance to ensure the livelihood and welfare of the fishers and fish farmers through various schemes which are as follows.

Sl. No.	Particulars	Reference
1.	Pradhan Mantri Matsya Sampada Yojana (PMMSY)	https://pmmsy.dof.gov.in/
2.	MSME schemes	https://msme.gov.in
3.	NABARD schemes	www.nabard.org.in
4.	NFDB schemes	https://nfdb.gov.in/
5.	Tamil Nadu state schemes	https://www.fisheries.tn.gov.in
6.	District Industries Centers schemes	https://www.msmetamilnadu.tn.gov.in/dic.php