Fisheries and Aquaculture

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Abstract

India, a country with rich aquatic diversity endowed with vast aquatic resources has made tremendous progress in the field of fisheries and aquaculture. At the national level, the GDP contribution of Fisheries to Agriculture is 7.28%. At the global level, India holds the second rank in aquaculture. But looking back there are many Individual, Institutional and Governmental efforts in achieving present day's success. At the individual level, the contribution of Dr. Hiralal Chaudhuri for the development of artificial spawning is a major landmark. Development of induced breeding followed by composite fish culture during the 1980s revolutionized the sector, today which we term as Blue Revolution. At Institutional Level various research Institutes were established like Central Inland

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P. K. Ghosh et al. (eds.), *Trajectory of 75 years of Indian Agriculture after Independence*, https://doi.org/10.1007/978-981-19-7997-2_13

Fisheries Research Institute (CIFRI), Central Marine Fisheries Research Institute (CMFRI), Central Institute of Freshwater Aquaculture (CIFA), Central Institute of Brackishwater Aquaculture (CIBA), Central Institute of Fisheries Education (CIFE), Central Institute of Fisheries Technology (CIFT), Directorate of Coldwater Fisheries Research (DCFR), National Bureau of Fish Genetic Research (NBFGR) to develop cutting edge aquaculture technologies. Noticeable technologies that need to be highlighted are Captive breeding of high-value freshwater, brackishwater and marine species, Development of improved variety of fish species, Enclosure culture, Disease management, Feed Management, Cataloguing and conservation of novel species, etc. A lot has been achieved, but there are several challenges that also need to be addressed like climate change, the emergence of new aquatic diseases, fulfilling the feeding requirement, the establishment of value chains and domestic market linkages, development of motivated entrepreneurs. Besides, there is also a need for the development of information and communication technology and precision farming in this field. The whole idea in developing this sector further will be sustainable development of fishers and fisheries for a better tomorrow in the form of economic growth, nutritional fulfilment with a healthy environment.

Keywords

Fisheries · Aquaculture · Pre-independence · Post-independence · Growth and development · Blue revolution

13.1 Introduction

India, a blessed country with rich and diverse natural resources, is endowed with a wide plethora of aquatic and fisheries resources ranging from deep seas to lakes, ponds, and rivers more than 10% of the global biodiversity in terms of fish and shellfish species. India is bested with marine fisheries resources that are spread along the country's vast coastline with Exclusive Economic Zone (EEZ) of 2.02 million square km and a continental shelf of 0.53 million sq. km. The inland resources are in the form of reservoirs (31.5 lakh hectares), floodplain lakes (8.12 lakh hectares), brackish water (12.4 lakh hectares), rivers and canals (1.95 lakh km), ponds and tanks (24.1 lakh hectares), saline/alkaline affected areas (12 lakh hectares), etc. Fish production in India has shown tremendous growth that can be understood by the increase of production from 0.75 million MT during 1950–1951 to the current production of 14.1 million MT (Figs. 13.1 and 13.2). Apart from this, Fisheries and aquaculture-based activities serve the livelihood of 15 million people. On average around 50 different types of Fish and shellfish are being exported to 70 nations. In terms of quantity fish and processed products contribute to 14 lakh tonnes and in terms of value, they contribute INR 46,000 crores to agricultural export of the nation. Fisheries sector contributed around Rs. 2100 billion to the country's GVA. This accounted for 7% of the agricultural GVA and 1.25% of the

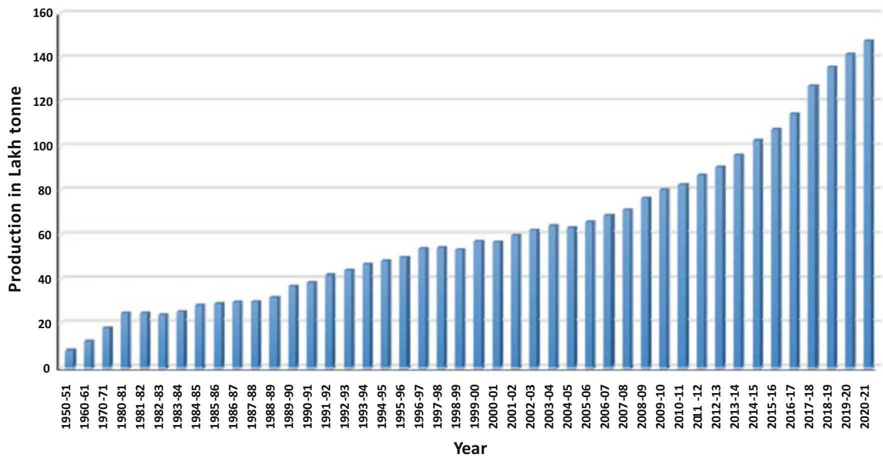

Fig. 13.1 Fish production scenario of India. (Handbook on Fisheries Statistics 2000, GOI)

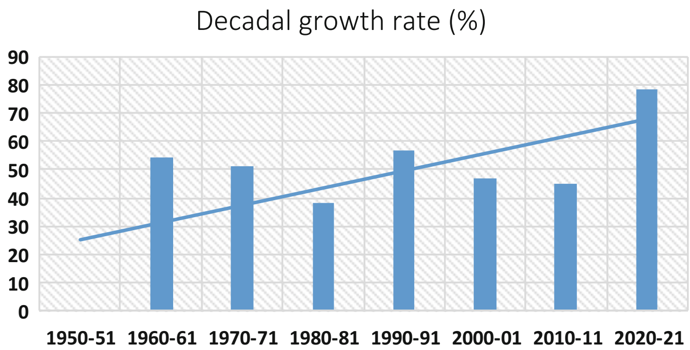

Fig. 13.2 Decadal growth rate in fisheries production. (Data from Handbook on Fisheries Statistics 2014, GOI)

total GVA in the year 2018–2019. This sector with a growth rate of 10% recorded the highest among the other agricultural sectors.

Fisheries and aquaculture are sunshine sectors because of their faster growth than the crop and livestock sectors (Kumar et al. 2006). But everything was not as rosy as it appears now. Indian Fisheries and Aquaculture have continuously evolved and developed with many stakeholders and professionals' continuous and untiring efforts. To know it, we must travel to the past and dig out some of the significant contributions of the sector.

13.2 Status of Fisheries in Pre-Independence and Independence Era

The recorded observation of fish occurrence in India can be traced back to 3 millennium BC. Evidence of fish imprints being used for human consumption has been found in Mohenjodaro and Harappa of Indus Valley Civilizations (2500 BC–1500 BC). In a book compiled by Mansoltara in 1127 AD, King Someswara and King Vikramaditya VI were the first to record the common sport fishes of India and they had further classified them into freshwater and marine fishes.

The foundation for modern scientific research in fisheries dates back to the British era when various Naturalists, Taxonomists, Zoologists and Botanists recorded the fishes and other aquatic organisms from India and catalogued them. A veterinary surgeon by profession Sir Francis Day contributed significantly to catalogue of the fishes of India through his research articles and monographs. Indian Fisheries Act is a stepping stone in our history that conferred upon the rights of developing fisheries to the different provinces in their respective states.

Traditionally aquaculture has been in practice for self-consumption and local trade in the eastern part of the country in small homestead ponds. During the nineteenth century, advances were made over the traditional homestead aquaculture with the breeding of carps in controlled conditions with the simulation of river-like conditions. Pisciculture was popularized in the state of Tamil Nadu followed by other states like Uttar Pradesh, West Bengal, etc. with the establishment of Fisheries Departments. The Indian fisheries sector was characterized as primitive, ignorant, unorganized, ill-equipped and caste-based by the National Planning Committee in 1946 (Kurien 1985), suggesting a social rigidity that would prevent economic efficiency (Karnad 2017).

Owing to this status, much attention was paid to the planned development of this sector through 5-year plans and the establishment of technical research organizations. As a result of this, in 1947, two major research stations were set up under the Ministry of Food and agriculture: The Central Inland Fisheries Research stations (CIFRS) in Kolkata, West Bengal and Central Marine Fisheries Research Stations (CMFRS) in Mandapam, Tamil Nadu (Silas 2003).

Traditionally spawns were collected from rivers during the breeding season (Fig. 13.3). The artificial spawning of minnow *Esomus danricus* through pituitary injection was a remarkable achievement by Prof. Hiralal Choudhuri in the year 1955. This was followed by the captive spawning of other culturable species like Rohu, Bata, Mrigal and many other cultivable species during 1957 (Chaudhuri and Alikunhi 1957). This was the first-ever aquaculture breakthrough, which impeded the subsequent Blue Revolution. The Indians were the first to develop hypophysation technique for artificial captive breeding of Indian Major Carps, way ahead of the Chinese, who created the same method for Chinese carps in 1958.

Subsequently, after mastering the art of captive breeding of fish, another significant achievement was using synthetic artificial inducers in fish breeding. During the 1970s and 1980s, due to the paucity of carp pituitary extracts, research was targeted to use Human Chorionic Gonadotropin (HCG) for breeding. Various synthetic

Fig. 13.3 Collection of riverine fish seed using a *gamcha,* a rectangular mosquito netting cloth. (*Pic. Courtesy: CIFRI, Barrackpore from web*)

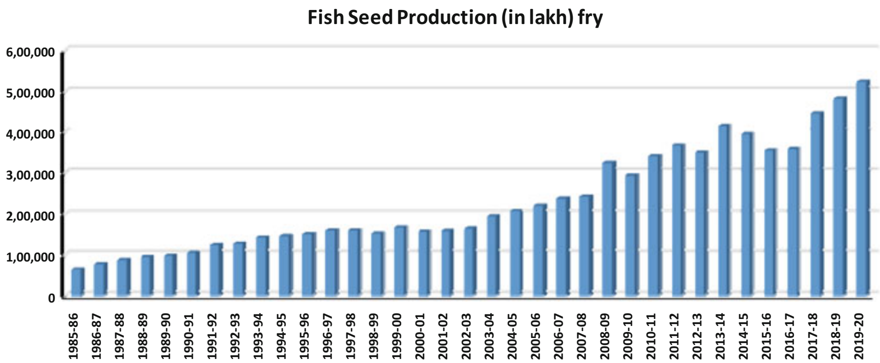

Fig. 13.4 Fish seed production scenario of the country. (Data from Handbook on Fisheries Statistics 2020, GOI)

hormones are available in the market with different combinations and trade names like ovaprim, ovatide, Wova-FH, etc. Because of these artificial hormones, fish seed production was boosted by from 63,000 lakh fry in the 1980s to over 5 lakh fry in the present day (Fig. 13.4). Subsequently, because of these technological advancements, riverine seed collection and bundh breeding became obsolete.

Scientific carp farming was established in India with the launch of an All India Coordinated Research Project (AICRP) on 'Composite Culture of Indian and Exotic Fishes' by the CIFRI in 1971 where as demonstrations as high as 8–10 tonnes/ha/ year was obtained. This AICRP was operated in 12 centres across the country until 1984. It was followed by the launch of three more AICRPs on 'Spawn Prospecting', 'Air-breathing Fish Culture' and 'Brackish water Fish Culture' (FAO 2003). Because of all these efforts, farmers were convinced to take up carp seed production and culture as a business enterprise in different parts of the country like Andhra Pradesh, Punjab, Haryana, Maharashtra, etc. leading to a blue revolution in the country. Govt launched the formal Blue Revolution in India during the seventh 5-Year Plan (1985–1990) on the occasion of the Fish Farmers Development Agency (FFDA) sponsorship.

13.3 The Blue Revolution Era

13.3.1 Technologies in Freshwater Aquaculture

13.3.1.1 Composite Fish Culture

Hypophysation and Captive breeding laid the foundation of modern scientific aquaculture in the country, The third significant breakthrough in bringing about the blue revolution in the country was composite fish culture, i.e. the culture of compatible combinations of Indian and Chinese carps, i.e. culturing of fish based on their biology, habitat, feeding and compatibility (Alikunhi et al. 1971). From a meagre production of 600 kg/ha/year traditionally, it has been made possible to obtain a show of 15,000 tonnes/ha/year through composite fish culture with scientific management practices.

Till 2000, marine fish production dominated India's total fish production. However, due to improved management practices adopted through scientific backing, inland fisheries and aquaculture have taken a U-turn and presently contribute almost 90% of total fish production from a contribution of 46% in the 1980s.

India holds the second rank in aquaculture at the global level. Freshwater aquaculture production registered a 10 times growth from 0.37 million tonnes in 1980 to 9.0 million tonnes in the present time. Currently, the growth rate is hovering over 6% and contributing to more than 95% of the total aquaculture production. The main species in freshwater aquaculture are *Labeo rohita*, *Catla* and *Cirrhinus mrigal*. They are contributing to around 75% of the total production. The rest 25% is coming from Chinese carp and catfish.

It is estimated that only about 40% of the available area of 2.36 million hectares of ponds and tanks has been put to use and immense scope for expansion of the area exists under freshwater aquaculture (Handbook of Fisheries and Aquaculture 2013). Due to different schemes under the blue revolution, the national average productivity has risen from 600 kg/ha/year to 3000 kg/ha/year in a span from 1974 to the present times.

Technology of Intensive carp culture developed by ICAR-CIFA has the capacity to produce 10–15 tonnes/ha/year with supplementary feeding, aeration and biofertilization with Azolla (Tripathi et al. 2000). There are many progressive fish farmers who are achieving a higher production from 8 to 12 tonnes/ha/year (Handbook of Fisheries and Aquaculture 2013).

Technologies of induced carp breeding and composite fish culture in captive conditions converted the otherwise traditional sector into a lucrative, viable commercial enterprise. Breeding technology has been standardized for around 50 species of food and ornamental category (Raizada et al. 2019). Another technology developed by ICAR-CIFA called Multiple Spawning has the potential to produce 2–3 times more spawn compared to traditional breeding practices (Gupta et al. 1995). Much advancement was made in modernizing the traditional hatchery system. The eco-hatchery and FRP carp Hatchery could provide an impetus to fish seed production in the country.

13.3.1.2 Freshwater Prawn Culture

Macrobrachium rosenbergii, *M. malcolmsonii* and *M. gangeticum* are three freshwater prawn species brought into the culture system because of high consumer demand. The production of freshwater prawns is 10,000 tonnes during the present time. But it was 35,000 tonnes during 2002–2003. Andhra Pradesh was the chief contributor to the sector with a 73% contribution from an area of 38,820 ha (MPEDA). Because of the introduction of exotic Vannamei, production has declined in present times. But this scenario can be improved through popularization in landlocked parts of the country with standardization of seed production in artificial seawater.

13.3.1.3 Cold Water Aquaculture

Recognizing the necessity of cold water fisheries, ICAR-CIFRI started a cold water unit in 1963 to assess and utilize the fisheries resources available in this sector. Subsequently, it was given the status of NRC on Coldwater Fisheries in 1987 and further upgraded to the status of Directorate on Coldwater Fisheries Research in 2008. The institute has mapped and documented 258 species, 76 genera and 21 families of the Coldwater fish resource. This resource accounts for 17% of the total fish fauna of the country. Out of these, 203 species have been recorded from the Himalayas and 91 from the Deccan Plateau Total fish production from hill states is only 75,000 MT, accounting for 1.5% of the country's inland production. Food fishes of cold waters are mahaseer and schizothoracids belonging to the indigenous species and trouts among the exotic varieties. Schizothoracids and Mahseers support capture and sport fisheries, whereas aquaculture is limited mainly to carp culture in mid-hill cold waters and rainbow trout in higher altitudes.

13.3.1.4 Flood Plains and Wetlands

There are around 31.5 lakh hectares of small, big and medium reservoirs in the country. ICAR-CIFRI has developed various technologies for improving the productivity of these reservoirs. Notable among these are fish seed ranching and cage culture. Due to these technologies, productivity could be increased to 500, 200 and 100 kg/ha/year from the small, medium and large reservoirs, respectively. Floodplains/wetlands are productive ecosystems that can be effectively utilized for aquaculture. Enclosure fisheries like cage and pen culture developed by ICAR-CIFRI has resulted in increasing the productivity from 200 to 400 kg/ha/year.

13.3.1.5 Scientific Interventions in Culture Practices

Diversification is an essential practice for the long-term sustainability of the sector. It was also realized in due course of time, that aquaculture is being dominated by a few Indian major carps and Chinese carps. To address this and to make the whole system more sustainable, species diversification with various endemic species with local and regional demand like *L. gonius, L. bata, Cirrihinus cirrhosa, Puntius sarana, L. dussumieri, P. jerdoni, Labeo calbasu, C. reba, L. fimbriatus* were also introduced into composite fish culture system (Jena et al. 2020).

Catfish breeding and culture were considered a national priority. Under that, ICAR-CIFA standardized several catfish species' breeding and culture techniques like Magur (*Clarias batrachus*), Singhi (*Heteropneustes fossilis*), Murrels and *Anabas testudineus,* etc. A production of 3–5 tonnes of Magur could be demonstrated in small shallow ponds in a duration of 6 months.

Monoculture and Polyculture of Pabda has been standardized and popularized in eastern and North eastern parts of the country.

Many exotic species were introduced to the country because of their fast growth. Notable among them are *Pangassius, Pangassius sutchi*. *Pangasius sutchi*, was introduced to India in 1995–1996 from Thailand to the state of West Bengal. This fish has the potential to grow up to 1.5 kg in a year with a production capacity of 20 tonnes/ha/year (Belton et al. 2017). The Government of India has stipulated strict guidelines for regulating the introduction of *P. sutchi* in the country. The guidelines suggested keeping the upper limit of production to 20 tonnes/ha/year.

Another exotic fish that Govt has permitted is *Oreochromis niloticus* in 2012 with a prescribed set of guidelines for the propagation of the species. As per the guidelines, farming of monosex male/sterile is permitted.

The scientific basis of culture techniques were standardized for nursery, rearing and grow out ponds for spawn, fry and fingerling rearing respectively. Of the total farmers in the country 90% are small and marginal. Besides, there are farmers with high investment capacities. So technologies for all categories of farmers were developed and classified as Low, Medium and High input Technologies. In high input technology, also called high-tech aquaculture, there are two primary components that lead to higher production: Water exchange and aeration. Production levels of over 10–15 tonnes/ha/year have been possible through this system.

Then again, based on the production cycle, composite fish culture technology was classified into single stocking, single harvesting and multiple stocking multiple harvesting. In this system, marketable size fishes are harvested from ponds at regular intervals with periodical restocking.

Many scientific interventions have been done in Integrated fish farming. This integration has been most successful with livestock and horticulture with fish production of 3–55 tonnes/ha (Ayyappan and Jena 2003). This system is a very sustainable system as the by-products/wastes are utilized as principal inputs thereby making the farming practice highly remunerative and farmers friendly.

Traditional practices of Paddy and Fish culture were improvised based on location. Production of 500 kg fish and around 3 tonnes of paddy can be achieved from a hectare of land.

In the high altitude raceway culture has been standardized for commercially important species like rainbow Trout by ICAR-DCFR.

13.3.1.6 Technologies in Genetics, Nutrition and Health Management

Developing improved rohu (Jayanti) through selective breeding with a record of 17% higher growth response per generation after 11 generations is a significant achievement from ICAR-CIFA. Jayanti Rohu has recorded a 55% higher growth in farmers' fields in various parts of the country. Similarly improved Catla and freshwater prawn have recorded 2% and 10% higher growth, respectively.

Various types of fish feed like CIFABROOD™, CIFRI CageGrow, Vanamiplus, Varsha, Varna have been developed for freshwater, brackish water and marine water species. Private entrepreneurs have played a major role in the popularization of these feeds.

In the 1980s, Epizootic ulcerative syndrome, a transboundary disease caused huge economic losses to the farmers of the country. CIFAX™ as a prophylactic and therapeutic measure was developed by ICAR-CIFA to EUS. A National Surveillance Program for Aquatic Animal disease initiated through research Institutions along with NBFGR and NFDB is in place for aquaculture disease monitoring in India.

India is home to 10% of the global ichthyofaunal biodiversity. The database of ICAR-NBFGR records around 2650 fin fishes, which includes around 290 exotic species. (NBFGR). Out of around 2300 indigenous species, 880 fishes are found in freshwaters, 115 in brackish waters and 1350 fishes are found in marine waters, belonging to 39 orders, 225 families and 852 genera. The biodiversity-rich areas such as North East India and Western Ghats have been explored through various network programmes. The recent discovery of more than 39 new species warrants more intensive exploratory surveys to map further unknown resources (NBFGR).

13.3.1.7 Technologies in Brackishwater Aquaculture and Mariculture

Brackishwater farming in India is an age-old traditional system confined mainly to bheries (artificial impoundments in coastal wetlands) of West Bengal and Pokkali (Salt Resistant deep water paddy) fields along the Kerala coast. The fisheries in these systems involved trapping the seeds of fish and shrimps and culturing them without providing any external input. The first scientific attempt at developing various mariculture technologies in India was during the 1960s by ICAR-CMFRI (CMFRI). Initially, the focus was on marine molluscan species like Oyster, mussel, clam, etc., and the main species that were brought to culture practices were *Pinctada fucata, Pinctada maragaritifera* and *Crassostrea madrasensis* (Mojada et al. 2021).

In the early 1970s, the major was focused on the development of coastal aquaculture and mariculture mainly because of dwindling capture fisheries resources and export pressure. Consequently, important Penaeid species were bred in captivity at Narakkal farm of CMFRI like *Penaeus monodon, P. japonicus, P. semisulcatus,* etc. (Ponnaiah 2011).

As such the production was of subsistence level. ICAR launched AICRP on "Brackishwater Fish farming" in 1973 (CIBA). Under this project, several technologies of fish and shrimp farming were developed. The brackishwater aquaculture in India got its fillip with the demonstration by the DBT-sponsored project on semi-intensive shrimp farming at Nellore, Andhra Pradesh, by TASPARC, during 1989–1993 (CIBA). To provide further impetus to brackishwater aquaculture, ICAR-CIBA, a part of CIFRI, was established as a separate institute in 1985.

In the year 1997, ICAR-CIBA developed the technology for the breeding of *Lates calcarifer* throughout the year (Arasu et al. 2009). Then in the year 2015, the same institute developed the captive breeding technology of *Chanos* followed by the successful artificial breeding of *Mugil cephalus* in 2016. The culture technologies were also standardized for the above 3 species. Besides captive breeding of *Etroplus suratensis*, *Lutjanus argentomaculatus* and *Tenuilosa ilisha* were also standardised.

Another significant achievement is the promotion of Saline water aquaculture to transform wasteland into wetlands. Under this 13,000 ha have been covered with a production of 4331 tonnes with a productivity of 6 tonnes/ha. Many potential candidate species like *Etroplus, Chanos,* etc. have proven to be commercially suitable in inland saline areas. Production potential ranging from 0.5 to 3 tonnes/ha/year has been demonstrated from such waters (Handbook of Fisheries and Aquaculture 2013).

ICAR-CMFRI developed seed production and culture techniques for oysters and mussels in 1970s. Besides it has also developed induced breeding technology for Cobia and Silver pompano in 2010 and 2011 followed by seed production technology *for Epinephelus coioides* in 2013. Simultaneously culture practices of various fin fish species like Pompano, Cobia, Grouper etc. were standardized. Apart from this culture of crustaceans, oysters, mussels, clams, and seaweed culture was also practised. In the year 1972, CMFRI initiated a pearl culture program and successfully developed the technology for pearl production in Indian pearl oysters. The Mandapam Research Centre of CMFRI has developed the technology for the culture of agar-yielding algae Gracillaria and Gelidiella that led to a rise of entrepreneurship for producing agar in various areas of Tamil Nadu.

Biofloc Technology that operates on Zero water Wastage Concept has been in vogue in the present days. In a technology developed by ICAR-CIBA, 40–60 kg of finfish like Tilapia and 5 kg of shellfish like shrimp can be produced from a biofloc unit of 1 tonne capacity.

Integrated Multitrophic aquaculture or IMTA is a technology that utilizes different species at various trophic levels so that nutrient loads of fed species can be used as input for extractive species. ICAR-CMFRI has developed IMTA for Cobia with sea weed *Kappaphycus alvarezzi*.

The current mariculture production is to the tune of 0.01 million tonnes. For the first time in the country, Open Sea aquaculture was initiated by ICAR-CMFRI in 2005 by establishing the open sea floating cage in Vishakapattanam. Further refining technologies and adoption have led to the rapid spread of cage mariculture.

As a result of all these concerted efforts, brackishwater and mariculture gained momentum in our country. With only 13% of the area utilized under brackishwater aquaculture, the production is 0.7 million MT with a productivity of 4 tonnes/ha. In 1990s, MPEDA established shrimp hatcheries in Andhra Pradesh and Odisha that

Table 13.1 Technologies in freshwater aquaculture

Sl. no	Technology	Year
1	Induced breeding of *Esomus danricus* using pituitary gland extract	1955
2	Induced breeding of *Cirrhinus reba,* followed by three Indian major carps	1957
3	Induced breeding of Chinese carps	1962
4	Development of composite fish culture technology	1970
5	Breeding of Magur	1982
6	Intensive culture technology	1994
7	Selectively bred Jayanti Rohu was released	1996
8	CIFAX developed against EUS	1998
9	Diversified species were promoted, different culture techniques were developed	1999–2009
10	CIFABROOD™, a diet for broodstock was developed	2009

led to immense growth in the production. The most significant contribution was from Tiger shrimp *P. monodon*. A major havoc in the rapid growth of the shrimp hatchery was the white spot syndrome virus (WSSV) in 1994 when the industry experienced heavy losses. The time was to bring in alternate species to keep the industry running. *L. vannamei*, an exotic shrimp species fitted to the void with Government's strict control and monitoring measures. This species has the potential of 10–12 tonnes/ha in 3–4 months duration. The total shrimp production of the country is 8 lakh tonnes from an area of 1.7 lakh hectare. Ninety percent of the contribution comes from Vannamei. CIBA has played a crucial role in developing diagnostic kits for white–spot syndrome virus (WSSV), the first of its kind in India, and supported the formulation of best management practices (BMPs) for Indian shrimp culture to motivate and support the farmers to continue the production of Tiger shrimp along with vannamei production.

Shrimp export was the main reason for boost in India's export growth. Farmed shrimp production grew from 20 MT in 1947 to 7.47 lakh MT in 2020, thereby contributing to the major export share of INR 46,662 crores fisheries export earnings.

The major technological advancements that lead to blue revolution in the country have been summarized in Tables 13.1 and 13.2.

13.3.1.8 Major Schemes by the Government for the Promotion of the Sector

The first Blue Revolution was launched during the seventh 5-Year Plan (1985–1990) under the sponsorship of the Fish Farmers Development Agency (FFDA). Later during the eighth 5-year plan (1992–1997), the intensive Marine Fisheries Program was launched. Subsequently, it was decided by the Ministry of Agriculture and Farmers Welfare along with the Department of Animal Husbandry, Dairying and Fisheries to restructure this scheme along with all other ongoing plans under a single umbrella "Blue Revolution". The Blue Revolution in India and the Fish Farmers

Table 13.2 Technologies in brackishwater and mariculture

Sl. no	Technology	Year
1	Pearl culture programme initiated	1972
2	Culture techniques of agar yielding seaweed Gracillaria and Gelideiella was standardized	1974
3	Captive breeding and larval rearing of Penaeid species	1975
4	Culture techniques of mussel and oyster	1977
5	AICRP on brackishwater aquaculture	1987
6	Seed production techniques of *Lates calcarifer*	1997
7	Open sea aquaculture through cages	2005
8	Seed production of cobia	2010
9	Seed production of silver pompano	2011
10	Seed production of *Epinephelus cooides*	2013
11	Seed production and culture of *Chanos chanos*	2015
12	Seed production and culture of *Mugil cephalus*	2016
13	Biofloc technology for shrimp	2016
14	Integrated multitrophic aquaculture with fed and extractive species	2018

Development Agency (FFDA) improved the aquaculture and fisheries sector with the introduction of new techniques of rearing, marketing, exporting, and breeding.

Some of the significant outcomes of the first Blue Revolution in India are mentioned below:

1. From a meagre production of 60 thousand tonnes, Fisheries production reached 4.7 MT that included 1.6 Mt. from freshwater. India was recorded to achieve an average annual growth of 14.8% as compared to the global average percentage of 7.5 in the production of fish and fish products.
2. In the export scenario, the Fishery sector recorded a growth rate of 6–10%, thereby becoming the largest contributor amongst other agriculture sectors.
3. India became the world's second-largest producer of fish with exports worth more than INR 47,000 crores.
4. Globally India ranked second in aquaculture.
5. The fisheries and aquaculture production contributed 1% and 5% to India's GDP and Agricultural GDP, respectively.

13.3.1.9 Blue Revolution 2.0/Neel Kranti Mission

The focus of the Blue Revolution 2.0 is on development and management of fisheries. This covers inland fisheries, aquaculture, marine fisheries, including deep sea fishing, mariculture and all activities undertaken by the National Fisheries Development Board. The Government of India in December 2014 launched "Blue Revolution" Mission with a central outlay of INR 3000 crores. Under this scheme, it was aimed for a sustained annual growth rate of 6–8% in fish production. In these 5 years, main focus was on private investment and entrepreneurship development with capacity building and development of the value chain. The scheme was implemented from 2015–2016 to 2019–2020. The government under the MGNREGA started to develop the farm ponds, where pisciculture would take place.

The salient features of BR scheme and achievements made are given below:

- Different GOI projects to be converged and linked with Sagarmala project like MNREGA scheme, NRLM and RKVY. Increasing the yield as well as productivity in culture and capture fisheries from both inland and marine waters.
- Motivating the socially and economically backward sections particularly schedule castes and tribes to take up fishing-based activities. The Blue Revolution Scheme also encourages entrepreneurship development, private investment, Public-Private Partnership (PPP), and better leveraging of institutional finance.

13.3.1.10 Pradhan Mantri Matsya Sampada Yojana

Government of India launched its flagship scheme “Pradhan Mantri Matsya Sampada Yojana” as a COVID-19 relief package under Self Reliant India on 10 September 2020. The main focus was to bring about Blue Revolution in the country through responsible and sustainable development in Fisheries Sector. The total outlay of this scheme is INR 20,050.00 crores. The main features of this scheme are as follows:

- Enhancement of Production and Productivity.
- Infrastructure and Post-harvest management.
- Fisheries Management and Regulatory Framework.

The goals of PMMSY is additional fish production by 70 lakh metric tonnes, enhancing productivity to 5 tonnes/ha, increasing the export value to 1 lakh crores from 46 thousand crores and generating 55 lakh additional employment with an objective of doubling farmers income by the financial year 2025.

13.3.1.11 The Way Forward

The number of undernourished people in India is expected to rise to 70 million by 2050. To suffice the need for food and nutritional security of the underprivileged and to cater to the needs of individuals with increased living standards, fish and fishery products are going to play a vital role. With increased anthropogenic pressure and an ever-developing and expanding economy, resources like land, water, energy, labour, etc. are likely to deplete and diminish in the coming days. The average size of operational holdings has declined progressively from 2.28 ha in 1970–1971 to 1.55 ha in 1990–1991 and 1.23 ha in 2005–2006. Compared to the present situation, the per capita land holdings will be much smaller by 2050 (ICAR-CIFA). To meet the demand of the country, a contribution of 17.5 million metric tonnes/year needs to be contributed from fisheries. The per capita water availability was 5500 cubic metres in 1955, and it has reduced to 1850 cubic meters in 2008 and would be further reduced to 1250 cubic meters by 2050. This warrants an urgent need to make aquaculture activity sustainable on a long-term basis. Hence utilization of diverse water resources like seasonal ponds, irrigation water, open wells, etc. and reusing and recycling waste through recirculation, utilization of rainwater, etc. will be both a challenge and an opportunity. Also, value addition and processing need to be addressed in a larger dimension. The idea is to increase productivity by obtaining more values per unit of water used.

Aquaculture through feeding constitutes about 20% of total aquaculture production, and to increase the production three times by 2050, the fed fish culture practices are to be raised at least four times the present level and that is going to pose a major challenge. Since 1995, aquafeed production has grown globally at an average rate of about 10.7%/year. The output of formulated feed increased from 7.7 million metric tonnes in 1995 to over 35 million metric tonnes in 2010, and it is expected to reach around 70 million metric tonnes in 2020. The total volume of feed sold in 2010 was 60,000 tonnes of pelleted feed and 3,72,000 tonnes of extruded floating feed. Currently, the aquaculture sector uses nearly 20% of total available concentrated feed and by 2050, about 23 million metric tonnes of feed would be required considering the three-fold increase in aquaculture production (CIFA). The fish feed resources have multiple competitors like the dairy and poultry industries. The feed resources used are generally the by-products of agro-processing industries. The availability of these products depends on agriculture which is heavily dependent on different climatic variables like rainfall, temperature, etc. The last decade witnessed a 3–4 times increase in the price of fish feed ingredients. Therefore, the future will need to identify, analyse and utilize alternate ingredients in fish feed.

The disease will continue to be a menace in the growth of aquaculture in the country owing to increased globalization and trade, Intensification of framing practices, transboundary and continental movement of different stages of fish, the introduction of novel species, etc. Diseases account for 10–15% losses in aquaculture, which will continue to rise in the coming future. For disease management, Better Management Practices (BMPs) and Regulatory framework needs to be in place for both existing and emerging pathogens. In the shrimp industry, the development of specific-pathogen-free (SPF) broodstock and strict biosecurity protocols need to be strengthened. There are various novel biotechnological tools like Loop-Mediated Isothermal Amplification (LAMP), Bead Array, Microarray, Multiplex test, etc. for the exclusion of pathogens in aquaculture, which needs to be further refined and standardised. Bacteriophage therapies are already under and have proved useful in the prophylaxis and treatment of bacterial infections in aquaculture. Immunostimulants like lipopolysaccharide and vitamin C have proved effective in controlling diseases (Sahoo et al. 2016, 2017, 2020). Bioactive compounds from sea and plants could be explored to find novel molecules to treat diseases. The focus must be on making available low-cost, readily available farmer-friendly diagnostics, eco-friendly therapeutics, common cost vaccines, etc.

In India, there are basically two categories of farmers: Farmers with more extensive land holdings and farmers with small land holdings of less than 2 ha. This is again less in NE India where the average land holding is 0.54 ha. These farmers constitute 90% of the total farmers. Hence Research Organizations will have to develop technologies which should be feasible enough for upscaling and downscaling as per the need. These farmers will also need assistance in a package of practice for input use efficiency, value and marketing channels, etc.

East India is a hot spot of biodiversity, but even then, the significant species cultured are the Indian Major carps and Chinese carps. Diversification is essential for sustainability in future aquaculture practices. *Osteobrama belangeri* is a high-demand fish in Manipur, whose breeding and culture are practiced, but productivity enhancement can be taken up. Similarly, *Ompak bimaculatus* is preferred in Tripura and Assam. The of an economically viable and sustainable package of practice for the species in mono and polyculture systems is much more essential. There are a few cultivable species in the cold water region; *Labeo dyocheilus, L. dero, Neolissocheilus hexagonolepis,* etc. whose breeding, feed, culture practice need to be refined to introduce into the culture system. *Bangana devdevi,* a minor carp, has good potential as food fish. The composite culture of *Bangana devdevi* (locally known as Khabak in Manipur) and *Osteobrama belangeri* (Pengba) can be standardized in Manipur.

Other minor endemic carps such as *Semiplotus semiplotus* for the state of Arunachal Pradesh, Assam and Sikkim have more significant potential. The breeding and culture practice for the species can be taken up. Genetic selection of *Neolissocheilus hexagonolepis, Ompak bimaculatus, Osteobrama belangeri* and other minor carp species having demand and culture potential can be taken up.

The disease component may be a part of the selection programme. Since the genetic characterization of chocolate mahseer populations has already been done, selection should be the next step.

Integration with agriculture and horticulture is within reach of farmers as these traditional crops do not require much expertise, but the focus should be on the use of improved varieties. The same is with the rice cum paddy culture system, i.e. in Apatani (Arunachal) and Manipur where a rich resource such as water is available in plenty. The presently available fish stock for this purpose has lower productivity may be due to low genetic worth.

Total fish production from hill states accounts for 1.5% of the total production. But there is tremendous potential for hill aquaculture. Rainbow trout, a high-value species whose current production is just 700 tonnes, can be increased to ten times through technological improvement, commercialization and popularization.

Brackishwater aquaculture currently utilizes only 14% of the available resources, pointing out that it can significantly increase aquaculture production. Policymakers worldwide are of the consensus that in comparison to other sectors, growth originating in food production sectors can improve the livelihoods of small and marginal farmers. In this way, the Indian brackishwater aquaculture sector has tremendous potential and a prominent role to play with 857 million rural populations with access to brackishwater resources. Engaging them for the transition towards blue socio-economic growth, commonly called “Blue Growth”, is envisaged for 2050 (ICAR-CIBA).

India has enormous mariculture potential with 2.2 million sq. km of Exclusive Economic Zone (EEZ), 0.5 million sq. km of the continental shelf, 8129 km of coastline, and 1.2 million ha of brackishwater and 20 million ha for marine farming.

The country is still nascent in world marine and coastal fish production, with just about 3.08% contribution in 2018 (FAO 2020).

India needs to produce about 18 million tonnes of fish by 2030 as compared to 14.1 million tonnes produced through capture and culture. The additional fish production has to come through aquaculture. As stated in the National Policy on Marine Fisheries, 2017 (NMF), an assessment of the exploited fish stocks in EEZ indicated overcapacity in the territorial waters and noted that further increase in capture fisheries has limited scope. Hence steps for the promotion and further development in the mariculture sector are the only options for meeting the fish demand in the coming years. This is attainable, as the projected mariculture production based on the area available is four to eight million tonnes against the current output of fewer than 0.01 million tonnes.

Aquaculture and conservation can go hand in hand, as in the case of endangered white sturgeon, which has been successfully conserved through aquaculture. Hence the development of region-specific aquaculture and conservation practices can benefit aquaculture diversification and play a crucial essential role in the conservation of that species. Hence Research should be targeted to focus on conservation through aquaculture.

India has rich and diverse ichthyo-faunal biodiversity. The current genetic research in India is limited to only a few species. Hence capacity and infrastructure to undertake -scale genomic analysis is the need of the hour, focusing on comparative genomics and phylogeny study. Traits are essential for launching any breeding programme. But traits are not easy to manifest in phenotyping as they change according to environmental conditions. Tagging the polymorphism at the gene level and using them to map the QTLs through marker-assisted selection (MAS) can be done. This will enable efficient and precision breeding for improved and desired traits. Through this, genetic progress in breeding could increase by more than 50%.

Precision farming is another important aspect that needs to be focussed to optimize field-level requirements and management regarding farming practices, input requirements, environmental protection, and saving labour and energy to derive maximum outputs. Mechanizations and other work need to be further scaled up. Climate resilient Aquaculture technologies need to be popularized like Integrated Multitrophic Aquaculture (IMTA), Recirculating Aquaculture Systems (RAS), Raceways, Floating cages, Penculture, etc. Popularization of ICT-based innovative tools like sensors, automated solutions for water quality, feeders, aerators, etc. can be improvised and popularized for further improvement in the aquaculture sector.

As the purchasing capacity of the domestic consumer is increasing each day, supply chains should be strengthened to cater to the need of the domestic consumer instead of relying heavily on global markets. This is particularly relevant to shrimp, prawns and other highly valued fishes. Supply chain systems to collect farm produce and deliver it to human consumption are in high demand. Developing domestic fish markets with these networks will be an excellent opportunity to generate employment and business.

13.4 Conclusions

Fish production in India has registered an annual growth rate of more than 7%. India's total estimated fisheries potential is 22.31 million metric tonnes, out of which the marine fisheries potential is 5.31 million metric tonnes and inland fisheries potential is 17 million metric tonnes. It is also important to mention that 71% of marine fisheries potential and 58% of inland fisheries potential has been harnessed (2017–2018). The three Indian Major carps *Labeo rohita, Catla catla and Cirrhinus mrigala,* with a production of more than 1.8 million tonnes, contribute the significant chunk of production, followed by the Chinese carps: silver carp, grass carp and common carp (FAO 2003). Somewhere, in 2014 the culture fisheries surpassed capture fisheries globally as a source of seafood for human consumption (Tacon and Metian 2018). Fish production in the country has shown continuous and sustained increments since independence. Only after the Indian independence, has fisheries and agriculture, been recognized as an essential sector. There are lots that have been achieved, but there are several challenges that also need to be addressed like climate change, emergence of new aquatic diseases, fulfilling the feed requirement, establishment of value chains and domestic market linkages, development of motivated entrepreneurs. Besides there is also need for development of information and communication technology, precision farming in this field. The whole idea in developing this sector further will be sustainable development of fishers and fisheries for a better tomorrow in the form of economic growth, nutritional fulfilment with a healthy environment.

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