Aquaculture of Commercially Important Finfishes in South Asia

Edited by
Shiba Shankar Giri
Shaikh Mohammad Bokhtiar
Sangram Ketan Sahoo
Baidya Nath Paul
Sriprakash Mohanty

SAARC Agriculture Centre
South Asian Association for Regional Cooperation (SAARC)
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November 2019

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Food and agriculture are the keys to achieving the entire set of SDGs, and many SDGs are directly relevant to fisheries and aquaculture, in particular SDG 14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development). Fisheries and aquaculture have become the sources of food and nutrition security and livelihoods earnings of millions of the world. At present, the aquaculture and fisheries products are the most traded food commodity in the world with exports rising from US$8 billion in 1976 to US$243.5 billion in 2016 (FAO, 2018). This sector in South Asia has been developing rapidly, with 6% annual growth rate, over the last decade and is the fastest growing aquaculture sub-sector. Much of this increasing aquaculture production is attributable to the expanding freshwater aquaculture of food fish. However, aquaculture of commercially important finfishes are very limited in this region. The Asian countries that lead in marine and coastal finfish aquaculture currently are China, Indonesia, Malaysia, Vietnam, Thailand, Korea and Japan. Most of the culture systems in South Asia are small-scale or on experimental level to evaluate the feasibility of export oriented finfish aquaculture. The main constraints are unreliable wild seeds and lack of the technology for the finfish hatchery seed production. However, commercially important finfish culture in a number of SAARC countries – Bangladesh, India, Nepal, Bhutan, Pakistan and Sri Lanka are accorded priority in the planned developmental process due to their popularity and high demand along with significant contribution to the regional economy.

This book ‘Aquaculture of Commercially Important Finfishes in South Asia’ is published to share information on crucial aspects of finfish aquaculture targeting the trade and export opportunities, associated challenges, available policies and further interventions required to realize the importance of aquaculture of commercially important finfishes in South Asia.

Dr. S.M. Bokhtiar
Director
SAARC Agriculture Centre
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Chapter 1

Issues, Challenges and Future Needs of Commercially Important Finfish Aquaculture in South Asia

S. S. Giri
SAARC Agriculture Centre, BARC Campus, Farmgate, Dhaka-1215, Bangladesh
ssgiri1965@gmail.com

Introduction

The world’s population is estimated to reach 9.7 billion by 2050 from its current level of 7.8 billion (UN, 2019) with most of the increase occurring in developing countries. It is estimated that to meet the demand food production will need to rise approximately 70–100% from the current production level by 2050 (Godfray et al. 2010; Pretty et al., 2010) keeping in view the challenges of climate change, economic uncertainty and increasing competition for natural resources. The United Nations’ Sustainable Development Program offers a unique, transformative and integrative approach, through its 17 goals (SDGs), to achieve zero hunger in the world by 2030. Food and agriculture are the keys to achieving the entire set of SDGs, and many SDGs are directly relevant to fisheries and aquaculture, in particular SDG 14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development). Fisheries and aquaculture have become the sources of food and nutrition security and livelihoods earnings of millions of the world. In 2016 the global fish production was 171 million tons, of which aquaculture represented 47% of the total and 53% if non-food uses are excluded, and 88% of total fisheries production was utilized for direct human consumption (FAO, 2018). Currently representing 20% of all animal protein supply (FAO, 2015a; FAO, 2015b) fish and fish products are the most traded commodity in the world. The total fish sale value of fisheries and aquaculture production in 2016 was estimated at US$ 362 billion, of which US$ 232 billion was from aquaculture production. During this period about 35% of global fish production was entered in to international trade with exports rising from US$ 8 billion in 1976 to US$ 152 billion in 2017. Global demand for fish as vital food continues to rise, driven by population growth, higher incomes, urbanization, growing international fish trade and increasing relative preference for seafood protein (Naylor,
The per capita fish consumption in the world has grown from 9.0 kg in 1961 to 20.5 kg in 2017.

![Figure 1: Global captured fisheries and aquaculture production, 1990-2030](source)

![Figure 2: Leading aquaculture producers worldwide as of 2018, by country (in million metric tons)](source)
Scenario and prospects of aquaculture in the South Asian region

Finfish aquaculture is the fastest growing aquaculture sub-sector in Asia and has been developing rapidly with around 6% annual growth rate, over the last decade. Almost 90% of the global fish production takes place in Asia and the South Asian countries mainly India and Bangladesh, respectively ranked 2nd and 5th in aquaculture animal production in the world. Fisheries and aquaculture remained as the second largest export earnings in Bangladesh, next to garments, and during FY 2016-17, the sector earned BDT 4,287.64 crore. During 2017-18 the export earnings from fisheries and aquaculture was US$ 7.08 billion in India (DAHD, 2019), 253.1 million in Pakistan during year 2014-15, and 162.8 million US$ in Sri Lanka in 2015. In the past 40 years the rate of growth of exports from developing countries has been significantly faster than that of exports from developed countries. Globally 59.6 million people are engaged in the primary sector of capture fisheries and aquaculture, of which 85% live in Asia, followed by Africa (10%) and Latin America and the Caribbean (4%).

Much of the increasing aquaculture production is attributable to the expanding culture of food fish for the local consumption. Less attention is paid on the aquaculture of commercially important finfishes across the culture systems and environments. The commercially important freshwater finfishes, catfishes, snakeheads, eels etc. are aquacultured in South Asia, but to a very limited extent. The Asian countries that lead in marine and coastal finfish aquaculture currently are China, Indonesia, Malaysia, Vietnam, Thailand, Korea and Japan. Among the SAARC countries, India, since 1960s, have been trying to culture a number of marine fishes including – mullets, groupers, sea bass, milkfish and pearl spot. Bangladesh and Sri Lanka also have long been trying to develop the breeding and nursing protocol for a very popular marine fish, sea bass (*Lates calcarifer*) without much success. Although there are enough resources potential in South Asia the aquaculture of commercially important finfish is lagging behind. Most of the culture systems are at present on small-scale basis or an experimental level to evaluate the feasibility of the system. The main constraints are unreliable wild seeds and lack of the technology for the finfish hatchery seed production. However, commercially important finfish culture in a number of SAARC countries – Bangladesh, India, Nepal, Bhutan, Pakistan and Sri Lanka are accorded priority in the planned developmental process due to their popularity and high demand along with significant contribution to the regional economy.
### Table 1. Top 10 ASFIS species items by quantity in world aquaculture, 2017

<table>
<thead>
<tr>
<th>ASFIS species</th>
<th>Scientific name</th>
<th>ISSCAAP division</th>
<th>Number of countries farming the species item</th>
<th>World production quantity of the species item (live weight; tons)</th>
<th>Share of world production quantity of all species (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Eucheuma seaweeds nei</td>
<td><em>Eucheuma spp.</em></td>
<td>Aquatic plants</td>
<td>13</td>
<td>8 637 534</td>
<td>7.72</td>
</tr>
<tr>
<td>3. Grass carp (white amur)</td>
<td><em>Ctenopharyngodon idella</em></td>
<td>Freshwater fishes</td>
<td>38</td>
<td>5 519 487</td>
<td>4.93</td>
</tr>
<tr>
<td>4. Cupped oysters nei</td>
<td><em>Crassostrea spp.</em></td>
<td>Molluscs</td>
<td>9</td>
<td>4 905 215</td>
<td>4.38</td>
</tr>
<tr>
<td>5. Silver carp</td>
<td><em>Hypophthalmichthys molitrix</em></td>
<td>Freshwater fishes</td>
<td>37</td>
<td>4 704 673</td>
<td>4.20</td>
</tr>
<tr>
<td>6. Whiteleg shrimp</td>
<td><em>Penaeus vannamei</em></td>
<td>Crustaceans</td>
<td>36</td>
<td>4 456 603</td>
<td>3.98</td>
</tr>
<tr>
<td>7. Gracilaria seaweeds</td>
<td><em>Gracilaria spp.</em></td>
<td>Aquatic plants</td>
<td>7</td>
<td>4 311 040</td>
<td>3.85</td>
</tr>
<tr>
<td>8. Japanese carpet shell</td>
<td><em>Ruditapes philippinarum</em></td>
<td>Molluscs</td>
<td>7</td>
<td>4 228 206</td>
<td>3.78</td>
</tr>
<tr>
<td>9. Nile tilapia</td>
<td><em>Oreochromis niloticus</em></td>
<td>Freshwater fishes</td>
<td>78</td>
<td>4 130 281</td>
<td>3.69</td>
</tr>
<tr>
<td>10. Common carp</td>
<td><em>Cyprinus carpio</em></td>
<td>Freshwater fishes</td>
<td>78</td>
<td>4 129 100</td>
<td>3.69</td>
</tr>
<tr>
<td>Other species</td>
<td></td>
<td></td>
<td>n.a.</td>
<td>56 749 978</td>
<td>49.80</td>
</tr>
<tr>
<td>All species</td>
<td></td>
<td></td>
<td>196</td>
<td>111 946 623</td>
<td>100.00</td>
</tr>
</tbody>
</table>

### Table 2. Top 10 ASFIS species items by value in world aquaculture, 2017

<table>
<thead>
<tr>
<th>Top 10 ASFIS species item</th>
<th>World aquaculture (2017 value)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASFIS species</strong></td>
<td>Scientific name</td>
</tr>
<tr>
<td>1. Whiteleg shrimp</td>
<td><em>Penaeus vannamei</em></td>
</tr>
<tr>
<td>2. Atlantic salmon</td>
<td><em>Salmo salar</em></td>
</tr>
<tr>
<td>3. Grass carp (white amur)</td>
<td><em>Ctenopharyngodon idella</em></td>
</tr>
<tr>
<td>4. Silver carp</td>
<td><em>Hypophthalmichthys molitrix</em></td>
</tr>
<tr>
<td>5. Red swamp crawfish</td>
<td><em>Procambarus clarkii</em></td>
</tr>
<tr>
<td>6. Chinese mitten crab</td>
<td><em>Eriocheir sinensis</em></td>
</tr>
<tr>
<td>7. Common carp</td>
<td><em>Cyprinus carpio</em></td>
</tr>
<tr>
<td>8. Nile tilapia</td>
<td><em>Oreochromis niloticus</em></td>
</tr>
<tr>
<td>9. Bighead carp</td>
<td><em>Hypophthalmichthys nobilis</em></td>
</tr>
<tr>
<td>10. Japanese carpet shell</td>
<td><em>Ruditapes philippinarum</em></td>
</tr>
<tr>
<td>Other species</td>
<td>n.a.</td>
</tr>
<tr>
<td>All species</td>
<td></td>
</tr>
</tbody>
</table>

Available at WWW.fao.org/fishery/statistics/software/fishstatj/en.
Issues and challenges in South Asian Aquaculture

The South Asian aquaculture has many issues and challenges and are identified in different occasions (Giri, 2017).

Environmental issues

- Conversion of important ecosystems like lakes, mangroves and agricultural lands to aquaculture farms
- Salinization and pollution of land and water by effluents from aquaculture ponds
- Nutrient loading of coastal water bodies and estuaries
- Excessive use of ground water for filling ponds
- Transmission of diseases to the surroundings and neighboring ponds
- Introduction of exotic diseases which affects the native species
- Excessive use of drugs, antibiotics, and other chemicals for aquatic animal disease control
- Inefficient utilization of fish feeds resources for fish and shrimp production
- Negative effects on biodiversity caused by escape of non-native species introduced for aquaculture, and destruction of birds and other predators
- Water scarcity in south Asian region creates hurdles for aquaculture. Continuous shrinkage of water table, frequent droughts, changes in climatic and rainfall pattern, excessive use of underground water are the causes of water scarcity for fish farming.
- Conservation of fish biodiversity is an important responsibility for ecological balance in the natural water as well as for maintaining the genetic variability of the stock for future use. Introduction of new species, escaped fish from commercial cages, installed in open water bodies, developmental programs and damming harm the native aquatic biodiversity.
- Disease transmission by contamination either by commercial fishers (people engaged in fish catching- as a livelihood option) or by aquatic birds.

Social issues

The social issues related to aquaculture are conflicts over use of land, water and other natural resources. In South Asia many landless people live near the coast and depend upon fishing and harvest of other coastal resources for
their living. Many times, the big investors obtain the land through financial or political influences. Local people sometimes are unable to develop small aquaculture projects in prime areas because the land is occupied by big companies. These people have sometimes been forced from coastal land by aquaculture developers.

Local people often develop small aquaculture farms in coastal areas without adequate technical knowledge and capital, and without proper permission from the government. Such projects sometimes lead to environmental damage, and they often are abandoned within a few years.

Construction of aquaculture farms sometimes interfere with use of traditional resources for local communities. Pollution by aquaculture farms also may result in a decline in fish and aquatic organisms important as a local food source.

Insufficient access to capital and cash liquidity is one of the most commonly stated constraints to aquaculture development. However, small-scale farmers may lack the credibility and collateral for accessing formal credit, sometimes resulting in unfavourable borrowing from informal sources.

The excessive use of surface or underground water by the large companies for aquaculture farming very often lead to controversy.

Pollution to the neighbouring agricultural farms due to conversion of fertile lands into farms is another issue in aquaculture. Drinking water gets contaminated due to pond effluents and salinization. This is the reason in 1996 the Indian Supreme Court banned the construction of shrimp culture ponds, other than traditional or improved traditional ponds, within the Coastal Regulation Zone (CRZ) and within a kilometer of Chilka Lake in Odisha and Pulicat Lake in Andhra Pradesh states. The court also directed to establish an authority for protecting the environment of the coastal area. Following to this the Government of India passed the Coastal Aquaculture Authority (CAA) Act in 2005. The Coastal Aquaculture Authority has been founded and resorts under the Ministry of Agriculture. The organization issues licenses to eligible farms, feed companies and hatchery owners.

**Planning and management issues**

**Aquaculture Zoning:** The main purpose of delimiting geographical areas within which aquaculture will be allowed is to address the issue of equity. This would seem to be particularly important for marine areas. The general notion in most countries is that the sea belongs to all. The issuance of aquaculture permits is contrary to this belief, and the very idea runs into
opposition, and not only from direct users of the water areas concerned. When establishing a zone these issues must be addressed squarely.

**Technology transfer:** Transfer of technology in aquaculture among the SAARC member countries is an important aspect that needs to be given emphasis as the region possess two large global aquaculture players, India and Bangladesh. Also, the technological advancements need to be transferred to small and marginal farmers within a country to make aquaculture economically self-sufficient sector of food production.

**Diversification of Aquaculture:** So far only few candidate species are being aquacultured in the SAARC Region. Standardization of technologies for seed production for other many indigenous as well as exogenous finfish and shellfish and culture of sea weeds are other possibility of aquaculture diversification. Also, the diversification of aquaculture systems, cage culture, pen culture, raceway, flow-through, RAS can be new initiatives in aquaculture. Farm mechanization, pond automation, information and communication technology (ICT) through web service is identified as key areas to reduce the input cost, crop losses and to harvest healthy crops from the aquaculture ponds.

**Genetically improved aquatic species:** So far only a few genetically improved aquatic species have been brought into commercial aquaculture operations. But, the know-how to develop genetically modified fish is spreading. These genetically improved organisms (GMOs) should satisfy the desires of both the producers and the consumer. R&D efforts on Jayanthi Rohu have yielded fruitful results and introduction of GIFT Tilapia in India has opened up new vistas for genetically improved species.

**Public-Private Partnerships:** Another important aspect about the positive impact of aquaculture is the Public-Private Partnerships which can be seen in many areas of infrastructure development such as market facilities, cold storages, processing sector etc.

**Aquaculture insurance:** In view of the severe natural calamities and disease out breaks, aqua farmers are incurring huge losses. An insurance cover will at least ensure that finance is available to recommence culture operations.

**Investments:** Generally, there is low participation of private investors in the sub-sector due to various constraints in the procedures, lack of incentives, short term licenses with lengthy procedure for application dealing with several line agencies which cause the investigators discouraged.
Seed Certification: Seed Certification and accreditation programme is being implemented in few countries in the SAARC region, but it is necessary for developing BMPs.

Expansion of coastal aquaculture: Expansion has been given priority and the area near the coast which is hitherto lying fallow and assigned DKT lands are given Certificate of Cultivation in Andhra Pradesh state for a period of one year and which can be renewed. This will help many small and marginal farmers to take up shrimp/crab culture and take out their livelihoods.

Infrastructure Development: Poor infrastructure development for post-harvest care and value chain maintenance in aquaculture hiders the huge demand of exports.

Farm mechanization: Farm mechanisation, pond automation, information and communication technology (ICT) through web service is identified as key areas to reduce the input cost, crop losses and to harvest healthy crops from the aquaculture ponds.

Aquaculture value chain: At the moment, very less focused programs are available for the value chain in fisheries sector.

Database: Lack of reliable database relating to aquatic and fisheries resources

Issues related to export of aquaculture products

Fishery products are the most internationally-traded food commodities and they are subsequently at the forefront of food safety and quality improvement (Huss et al., 2004). Products from aquaculture are very often contaminated with harmful chemicals and biological agents. Consumers expect the best quality product in terms of appearance, freshness, nutritional value, size, price, safety and other characteristics. However, governmental regulations and inspections do not adequately assure the safety of the food supply in the SAARC region. The demand for improved quality and safety in the major markets of the European Union (EU), United States of America (USA), Canada and Japan have resulted in the renovation of fish inspection regulations for the implementation of HACCP-based systems, in conformity with the guidelines of the Codex Alimentarius Commission (CAC) (Neeliah et al. 2011). The USA seafood importing guidelines requires every seafood product imported to USA should have Country of Origin Labeling (COOL) and Method of Production (MOP) labeling on the products, and the consumers are made aware since
implementation of the guidelines in 2004 of where a seafood product originated and if it was the result of aquaculture or fishing. Therefore, the products exported to USA from South Asian countries very often face the pain of rejection, causing heavy loss to the exporters.

**Commercially important finfish resources of freshwater, brackishwater and marine water in South Asia**

**Freshwater species**

The historical scenario of Indian fisheries reveals a paradigm shift from marine dominated fisheries to a scenario where inland fisheries has emerged as a major contributor to the overall fish production in the country. At present inland fisheries has a share of 66.81% in total fish production of India and aquaculture shares over 63% of total fish production. The last 10 years witnessed the tremendous aquaculture growth of 6-8% in the South Asian region. However, most forms of aquaculture are perceived to have adverse environmental effects (Tucker et al.; Klinger and Naylor 2012). At present more than two dozen of freshwater species of commercial importance are in Indian aquaculture systems. The cyprinids are the major group of freshwater species cultured followed by the catfish. In recent years, catfishes such as striped catfish, magur, singhi, pabda and the air breathers such as murrels and climbing perch are emerging as potential species for aquaculture.

In Bangladesh the contribution of Aquaculture is 55.15% of total fisheries production and is growing at 8.2% annually (APCAS, 2016). Carps contribute 33.57% of total annual fish production in the country followed by Pangas (Pangasianodon hypophtalmus) (11.04), and tilapia (Oreochromis niloticus) (8.44%). Apart from Indian major carps (IMCs), kalbasu (Labeo kalbasu), Gonia (Labeo gonius), Bata (Labeo bata), Singi (Heteropneustes fossilis), Magur (Clarias magur), Pabda (Ompok pabda), Gulsha (Mystus cavasius), Chitol (Chitala chitala), Shoal (Channa striatus), Cuchia (Monopterus cuchia), Koi (Anabas testudineus), Gang magur (Hemibagrus menoda), Rita (Rita rita) and Mohashol (Tor tor) are important freshwater species of commercial importance. There are about 40–50 small indigenous fish species which grow to a maximum length of 25 cm found in open waters of Bangladesh are of economic importance. Among them Gulsha (Mystus gulio), Pabda (Ompok pabda), Puti (Puntius sarana) and Mola (Amblypharyngodon mola) are being cultured in inland water bodies (ponds and lakes) (Hossain, 2014).

The commercial farming of mono-sex tilapia in ponds and cages getting momentum in Sri Lanka. The tilapia farming with the use of minimum
water and recirculation system started in Gampaha district is very popular in other parts of the country. The freshwater finfish production from aquaculture and culture-based fishery were 389.5 and 2239 t, respectively during 2018.

Several indigenous and exotic fish species are farmed for food and recreational purposes in Nepal. The three major Indian carps, common carp (Cyprinus carpio), Chinese carps and Bighead carp (Aristichthys nobilis) have been cultured in the country. At present rainbow trout farming is done in eleven districts of Nepal. Also, recently, Nile tilapia (Oreochromis niloticus), Java barb (Barbonymus gonionotus) and giant river prawn (Machrobrachium rosenbergii) are introduced in aquaculture to study their commercial production potential (Shrestha, 1999). Three high-valued indigenous coldwater fish species popular for their delicacies are, Asala (Schizothorax sp.), Katle (Acrossochielus sp.) and Mahseer (Tor sp.) also under consideration for commercial farming.

The land locked country Bhutan is predominant with fresh water species with six species of carps being the main stay of aquaculture industry of the country. Catla catla, Labeo rohita, Cirrhinus mrigala, Cyprinus carpio, Hypophthalmichthys molitrix, Ctenopharyngodon Idella, Chocolate Mahaseer (Accrossochelius hexagonolepis) and Golden Mahaseer (Tor putitoraI) are the major species of economic importance. Indian major carps, Chinise carps, common carp, tilapia, rainbow trout and brown trouts are the major species of commercial importance in Pakistan.

**Brakishwater species**

Brackishwater finfish culture in South Asia mostly depends on seeds from natural waters. In India few finfish species are under cultivation are seabass (Lates calcarifer), mullets (Mugil cephalus), pearlspot (Etroplus suratensis), milkfish (Chanos chanos) and cobia (Rachycentron canadum). In Bangladesh Bhetki (Lates calcarifer), Bhangan Bata (Mugil cephalus), Parse (Chelon subviridis) and Nunatengra (Mystus gulio) are the important species of brackishwater aquaculture. Similarly, in Sri Lanka Lates calcarifer and Chanos chanos aquaculture is getting momentum.

**Mariculture species**

The technologies for seed production and grow-out culture of cobia (Rachycentron canadum), groupers (Epinephelus sp.) and pompano (Trachynotus blochii) have been developed in India. In recent years, lots of emphasis is being given on cages farming of these species in sea. Maldives with World Bank assistance started aquaculture of groupers. Sea cucumber
is widely cultivated in Maldives. Now a days Sri Lanka is giving lots of importance on mariculture of *Lates calcarifer*, *Chanos chanos*, *Epinephalus* sp., *Lutjanus* sp., *Pampus argenteus*, *Pagrus major* and *Rachycentron canadum*. Non-availability of assured seed supply of these species is posing major bottleneck for expansion of their aquaculture.

**Outlook**

In assessing future challenges for the aquaculture sector in South Asia, SAARC has identified a number of key issues that span the entire sector, and which are of primary policy importance. A SAARC level regional consultation was conducted on quaculture of commercially important finfishes in South Asia, in Colombo, Sri Lanka during 26-28 March 2019. The recommendations were drawn to address the challenges of aquaculture of commercially important finfish aquaculture in South Asia.

**Policy**

- Spatial planning and zoning to keep aquaculture within the surrounding ecosystem’s carrying capacity and to lessen conflicts over resource uses
- Development and promotion of cooperative system to facilitate inputs and to lift the products from the finfish aquaculture site
- Introduction of aquaculture insurance program that provides coverage for losses and damages
- Networking and collaboration for capacity building between research and development institutions among regional, international and donor country research centres
- Policy guidelines involving the participation of the private sector in aquaculture researches in all aspects from production to trade
- Establish procedures to undertake appropriate environmental impact assessment and monitoring to minimize adverse ecological changes due to aquaculture

**Trade**

- Development of SAARC regional BMP, standards for fish and fish products, farm-based Hazard Analysis and Critical Control Points (HACCP) food safety systems and mechanisms to enable product traceability
- Processing and value addition of aquaculture products for export as well as local market
• Maintain and promote security of access to international trade, and proactive measures to avoid tariff and non-tariff trade restrictions

Social
• Empowering communities and strengthening community participation in aquaculture and its management
• Introducing incentives to reward sustainability through access to training, water supply, wastewater treatment, low-interest loans and tax exemptions to small and marginal farmers

Environment
• Regulatory to protect biodiversity in SAARC regional water bodies from irresponsible aquaculture practices
• Leverage the latest information technology (ICT) in aquaculture
• Vulnerable species may be identified and prioritized for conservation
• Expansion of the farming of fish species of lower trophic level, least water exchange systems, use of SPF and SPR strains and other management options to adapt to climate change impacts
• Moving towards reduction of carbon foot print in aquaculture
• Zone-wise commercially valuable stress tolerant species may be identified and cultured for better adaptation to climate change impacts
• Integration of aquaculture, livestock, agriculture and other production systems or ecosystem management activities
• Promote locally available resources in aquaculture to reduce production cost

References


Development of Aquaculture for Commercially Important Finfishes in India

Pratap Chandra Das
ICAR-Central Institute of Freshwater Aquaculture, India
pratapcdas@yahoo.com

Aquaculture scenario

Fish forms an important food item and source of animal protein in the food basket of almost half of Indians. Proved as a safe and quality animal protein source, its demand has been increasing day by day with the increased health consciousness as well as income of the consumers. The country has also made successful effort to comply with the fish demand. Being a maritime state, the huge potential of fresh-, brackish- and marine- water resources are being effectively utilized to increase fish production through development of capture fisheries and aquaculture activities. The sector also has transformed itself into an excellent employment avenue with over 16.1 million people engaged at the primary level and many more along the value chain. The total fish production in the country has witnessed phenomenal 3.03-fold increase from 4.16 MMT in 1991-92 to 12.59 MMT in 2017-18 (Fisheries Handbook, 2019). At present, India is the second largest fish producer of the globe and also ranks second in freshwater aquaculture production. Besides catering to the domestic fish demand, the sector has also proved to be an important foreign exchange earner with export value reaching to Rs. 470.894 billion (US$ 6.7285 billion) (Fisheries Handbook, 2019). The sector contributed about 0.92% to the National Gross Value Added (GVA) and 5.23% to the agricultural GVP in 2015-16 (DAHD&F, 2018). However, the country is yet to match the world’s projected per capita fish requirement of 21.5 kg in 2030 as against current availability at 9.6 kg per caput. Further, with the population growth at 1.01% in 2018 (http://worldpopulationreview.com/countries/india-population/, site visited in January, 2020), the country is adding approximately 13 million populations every year and there has been a continuous shift in the food habit oriented towards fish as a safe protein source, which is more likely to widen the demand supply gap in the coming years.

Fish production in India since mid-1980s is depicted in Fig. 1. Of the total production of 4.157 MMT in 1991-92, the marine sector was the major...
producer with 58.9% share (2.447 MMT) compared to the inland sector with 1.710 MMT (41.1%) (DAHD & F, 2018). But the trend has been reversed at present with the contribution from inland sector reaching at 70.7% (8.902 MMT), compared to 3.688 MMT (29.3%) from marine capture in 2017-18. The ICAR-CMFRI has estimated the marine fish landing at 3.88 MMT in 2017, which was 5.6% higher than the preceding year (CMFRI, 2018). The marine capture fisheries have been almost stagnant over these years and the sector has been recognized to reach the potential yield level (CMFRI, 2015). However, the inland sector has emerged during these years as the major producer to cater the increased fish demand in the country. Further, freshwater aquaculture has continuously increased its share of contribution in the inland fisheries from 34% in mid-1980s to about 82% in recent years.

Aquaculture in India until last decade had remained almost synonymous with farming of fish only in the freshwater sector. The freshwater fish farming itself has evolved from a state of homestead activity in 1950s to a promising venture and is being recognized as one of the most efficient agricultural enterprise. This has been realized with a series of research and development in all fronts of aquaculture coupled with well-planned strategy and implementation of many Central and State sponsored schemes through an efficient network of technology transfer. The freshwater aquaculture production, being contributing 82% of the inland production, mainly caters the domestic demand of the country. Brackishwater aquaculture mainly involves the shrimp farming and largely caters the export market. Inadequate seed availability and non-availability of appropriate culture technology for finfishes have been the limitation at present for the expansion of both marine and brackishwater aquaculture sectors. Such situation imposes the
responsibility to bridge the future gap of additional fish demand on the inland sector and particularly on the freshwater aquaculture sector. With the responsibility to double the fish production in coming 30 years, the aquaculture sector need to overcome several huddles, including water scarcity, diminishing land availability, climate change, labour shortage, environmental fallouts and so on. Besides, maintenance of economic vibrancy of the fish farming sector has been a major challenge to attract the small and marginal entrepreneurs into the venture. Production of a wide spectrum of fish species to meet the consumers’ choice and conservation of species diversity against anthropological pressure are possible under the sustainable aquaculture practices.

**Land and water resources for fisheries and aquaculture**

**Freshwater resources**

The country has huge freshwater resources in the form of 2.43 mha ponds and tanks, 2.93 m ha of reservoirs, 0.80 mha of floodplain lakes and derelict water and 0.19 million km of rivers and canals (Table 1). At present, only about 70% of the freshwater pond and tank resources are utilized for fish farming. The R&D activities on aquaculture during last five decades have led to the development of array of fish farming technologies to utilize almost all available kind of culture resources productively for fish production. The existing pond and tank resources are increasingly being brought under scientific farming every year with improved methodologies to increase fish production. Despite huge resources, the fish production potential of the reservoirs, floodplain lakes, derelict waters, rivers and canals is yet to be harnessed. Fish production from most of these open waters has been severely affected due to increased anthropogenic interference, viz., over exploitation, construction of dams and barrages that hinder breeding and feeding migration of endemic fishes, increased pollution, etc. However, with recent initiation of community participatory management of the open waters, enclosure farming (cage and pen culture) in reservoirs, promotion of culture based capture fisheries, promoting natural recruitment through fishing regulation, etc., have improved in yield. Improved fish productivity has been recorded in reservoirs, chaurs and mauns resources in eastern Indian states, Bihar, Chhattisgarh, Odisha, Jharkhand and the floodplain wetlands of Assam and West Bengal. The cold water resources are distributed in the medium to high altitudes of the Himalayan corridor in the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, West Bengal and all the north eastern states. While coldwater fish production amounts to only 3% of the total production, the production from culture is almost negligible and
limited to only few species. Off late, culture of exotic rainbow trout is being promoted in the cold water and expected to grow in the future.

Table 1. Inland resources of the different states of India

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>States/Union territories</th>
<th>River &amp; Canals (km)</th>
<th>Reservoirs (Lakh ha)</th>
<th>Tanks &amp; Ponds (Lakh ha)</th>
<th>Flood Plain Lakes &amp; Derelict Water Bodies (Lakh ha)</th>
<th>Brackish water (lakh ha)</th>
<th>Total Water Bodies (Lakh ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Andhra Pradesh*</td>
<td>11514</td>
<td>2.34</td>
<td>5.17</td>
<td>0.6</td>
<td>8.11</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Arunachal Pradesh</td>
<td>2000</td>
<td>2.76</td>
<td>0.42</td>
<td>-</td>
<td>3.18</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Assam</td>
<td>4820</td>
<td>0.02</td>
<td>0.23</td>
<td>1.1</td>
<td>1.35</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Bihar</td>
<td>3200</td>
<td>0.6</td>
<td>0.95</td>
<td>0.05</td>
<td>-</td>
<td>1.6</td>
</tr>
<tr>
<td>5</td>
<td>Chhattisgarh</td>
<td>3573</td>
<td>0.84</td>
<td>0.63</td>
<td>-</td>
<td>-</td>
<td>1.47</td>
</tr>
<tr>
<td>6</td>
<td>Goa</td>
<td>250</td>
<td>0.03</td>
<td>0.03</td>
<td>-</td>
<td>Neg.</td>
<td>0.06</td>
</tr>
<tr>
<td>7</td>
<td>Gujarat</td>
<td>3865</td>
<td>2.43</td>
<td>0.71</td>
<td>0.12</td>
<td>1.00</td>
<td>4.26</td>
</tr>
<tr>
<td>8</td>
<td>Haryana</td>
<td>5000</td>
<td>Neg.</td>
<td>0.1</td>
<td>0.10</td>
<td>-</td>
<td>0.2</td>
</tr>
<tr>
<td>9</td>
<td>Himachal Pradesh</td>
<td>3000</td>
<td>0.42</td>
<td>0.01</td>
<td>-</td>
<td>-</td>
<td>0.43</td>
</tr>
<tr>
<td>10</td>
<td>Jammu &amp; Kashmir</td>
<td>27781</td>
<td>0.07</td>
<td>0.17</td>
<td>0.06</td>
<td>-</td>
<td>0.3</td>
</tr>
<tr>
<td>11</td>
<td>Jharkhand</td>
<td>4200</td>
<td>0.94</td>
<td>0.29</td>
<td>-</td>
<td>-</td>
<td>1.23</td>
</tr>
<tr>
<td>12</td>
<td>Karnataka</td>
<td>9000</td>
<td>4.4</td>
<td>2.9</td>
<td>-</td>
<td>0.10</td>
<td>7.4</td>
</tr>
<tr>
<td>13</td>
<td>Kerala</td>
<td>3092</td>
<td>0.3</td>
<td>0.3</td>
<td>2.43</td>
<td>2.40</td>
<td>5.43</td>
</tr>
<tr>
<td>14</td>
<td>Madhya Pradesh</td>
<td>17088</td>
<td>2.27</td>
<td>0.6</td>
<td>-</td>
<td>-</td>
<td>2.87</td>
</tr>
<tr>
<td>15</td>
<td>Maharashtra</td>
<td>16000</td>
<td>2.99</td>
<td>0.72</td>
<td>-</td>
<td>0.12</td>
<td>3.83</td>
</tr>
<tr>
<td>16</td>
<td>Manipur</td>
<td>3360</td>
<td>0.01</td>
<td>0.05</td>
<td>0.04</td>
<td>-</td>
<td>0.1</td>
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<tr>
<td>17</td>
<td>Meghalaya</td>
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<td>0.08</td>
<td>0.02</td>
<td>Neg.</td>
<td>-</td>
<td>0.1</td>
</tr>
<tr>
<td>18</td>
<td>Mizoram</td>
<td>1395</td>
<td>-</td>
<td>0.02</td>
<td>-</td>
<td>-</td>
<td>0.02</td>
</tr>
<tr>
<td>19</td>
<td>Nagaland</td>
<td>1600</td>
<td>0.17</td>
<td>0.5</td>
<td>Neg.</td>
<td>-</td>
<td>0.67</td>
</tr>
<tr>
<td>20</td>
<td>Odisha</td>
<td>4500</td>
<td>2.56</td>
<td>1.23</td>
<td>1.80</td>
<td>4.30</td>
<td>9.89</td>
</tr>
<tr>
<td>21</td>
<td>Panjab</td>
<td>15270</td>
<td>0.07</td>
<td>0.07</td>
<td>-</td>
<td>-</td>
<td>0.07</td>
</tr>
<tr>
<td>22</td>
<td>Rajasthan</td>
<td>5290</td>
<td>1.2</td>
<td>1.8</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>23</td>
<td>Sikkim</td>
<td>900</td>
<td>-</td>
<td>0.03</td>
<td>-</td>
<td>-</td>
<td>0.03</td>
</tr>
<tr>
<td>24</td>
<td>Tamilnadu</td>
<td>7420</td>
<td>5.7</td>
<td>0.56</td>
<td>0.07</td>
<td>0.60</td>
<td>6.93</td>
</tr>
<tr>
<td>25</td>
<td>Tripura</td>
<td>1200</td>
<td>0.05</td>
<td>0.13</td>
<td>-</td>
<td>-</td>
<td>0.18</td>
</tr>
<tr>
<td>26</td>
<td>Uttar Pradesh</td>
<td>28500</td>
<td>1.38</td>
<td>1.61</td>
<td>1.33</td>
<td>-</td>
<td>4.32</td>
</tr>
<tr>
<td>27</td>
<td>Uttarakhand</td>
<td>2686</td>
<td>0.2</td>
<td>0.006</td>
<td>0.003</td>
<td>-</td>
<td>0.209</td>
</tr>
<tr>
<td>28</td>
<td>West Bengal</td>
<td>2516</td>
<td>0.17</td>
<td>2.76</td>
<td>0.42</td>
<td>2.10</td>
<td>5.45</td>
</tr>
<tr>
<td>29</td>
<td>A &amp; N Islands</td>
<td>-</td>
<td>0.00367</td>
<td>0.0016</td>
<td>-</td>
<td>0.33</td>
<td>0.33527</td>
</tr>
<tr>
<td>30</td>
<td>Chandigarh</td>
<td>2</td>
<td>-</td>
<td>Neg.</td>
<td>Neg.</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>31</td>
<td>Dadra &amp; Nagar Haveli</td>
<td>54</td>
<td>0.05</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.05</td>
</tr>
<tr>
<td>32</td>
<td>Daman &amp; Diu</td>
<td>12</td>
<td>-</td>
<td>Neg.</td>
<td>-</td>
<td>Neg.</td>
<td>0</td>
</tr>
<tr>
<td>33</td>
<td>Delhi</td>
<td>150</td>
<td>0.04</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.04</td>
</tr>
<tr>
<td>34</td>
<td>Lakashadweep</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>35</td>
<td>Puducherry</td>
<td>247</td>
<td>Neg.</td>
<td>0.01</td>
<td>Neg.</td>
<td>Neg.</td>
<td>0.01</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>195095</td>
<td>29.26367</td>
<td>24.3276</td>
<td>7.983</td>
<td>11.55</td>
<td>73.12427</td>
</tr>
</tbody>
</table>

*Including Telengana

Source: DAHD&F Annual Report, 2017-18
**Brackishwater resources**

The country with 1.16 mha coastal salt affected land and 3.9 mha of estuarine area has potentiality for brackishwater farming in its nine coastal states (DAHD&F, 2018). Besides, there are more than 7 mha inland saline areas in the land locked states of Punjab, Haryana, Uttar Pradesh and Rajasthan, which are suitable for brackishwater farming. Only 15% of the potential brackishwater resource is at present being utilized for commercial farming. The huge unutilized resources provide enormous scope for expansion of brackishwater farming activity in future.

**Marine resources**

The marine resource of the country comprises 8,118 km of coastline, 2.02 million sq. km of EEZ and 0.53 million sq. km of continental shelf area. The marine fishery potential of India has been estimated at 4.41 MMT (DAHDF, 2018). While there is little scope to increase the fish production from marine capture, development of cage farming has been given considerable attention for utilization of the open sea for fish production. Cage farming technique including the seed and grow-out production methods has already been standardized for few commercially important species which has opened up avenue to utilize the open sea. With a strong R&D support, the marine culture sector is expanding gradually and expected to significantly increase fish production in future (Table 2).

Table 2. Marine resources of the different States of India

<table>
<thead>
<tr>
<th>State/ Union Territories</th>
<th>Length of Coast Line (km)</th>
<th>Continental Shelf (’000 Sq. km)</th>
<th>Landing Centres</th>
<th>Fishing Villages</th>
<th>Fishermen Families</th>
<th>Fisher folk Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>974</td>
<td>33</td>
<td>353</td>
<td>555</td>
<td>163427</td>
<td>605428</td>
</tr>
<tr>
<td>Goa</td>
<td>104</td>
<td>10</td>
<td>33</td>
<td>39</td>
<td>2189</td>
<td>10545</td>
</tr>
<tr>
<td>Gujarat</td>
<td>1600</td>
<td>184</td>
<td>121</td>
<td>247</td>
<td>62231</td>
<td>336181</td>
</tr>
<tr>
<td>Karnataka</td>
<td>300</td>
<td>27</td>
<td>96</td>
<td>144</td>
<td>30713</td>
<td>167429</td>
</tr>
<tr>
<td>Kerla</td>
<td>590</td>
<td>40</td>
<td>187</td>
<td>222</td>
<td>118937</td>
<td>610165</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>720</td>
<td>112</td>
<td>152</td>
<td>456</td>
<td>81492</td>
<td>386259</td>
</tr>
<tr>
<td>Odisha</td>
<td>480</td>
<td>26</td>
<td>73</td>
<td>813</td>
<td>114238</td>
<td>605514</td>
</tr>
<tr>
<td>Tamilnadu</td>
<td>1076</td>
<td>41</td>
<td>407</td>
<td>573</td>
<td>192697</td>
<td>802912</td>
</tr>
<tr>
<td>West Bengal</td>
<td>158</td>
<td>17</td>
<td>59</td>
<td>188</td>
<td>76981</td>
<td>380138</td>
</tr>
<tr>
<td>A&amp;N Islands</td>
<td>1912</td>
<td>35</td>
<td>16</td>
<td>134</td>
<td>4861</td>
<td>22188</td>
</tr>
<tr>
<td>Daman &amp; Diu</td>
<td>27</td>
<td>0</td>
<td>5</td>
<td>11</td>
<td>7374</td>
<td>40016</td>
</tr>
<tr>
<td>Daman&amp;Diu</td>
<td>132</td>
<td>4</td>
<td>10</td>
<td>10</td>
<td>5338</td>
<td>34811</td>
</tr>
<tr>
<td>Puducherry</td>
<td>45</td>
<td>1</td>
<td>25</td>
<td>40</td>
<td>14271</td>
<td>54627</td>
</tr>
<tr>
<td>Total</td>
<td>8118</td>
<td>530</td>
<td>1537</td>
<td>3432</td>
<td>874749</td>
<td>4056213</td>
</tr>
</tbody>
</table>

Source: DAHD&F Annual Report, 2017-18
Commercially important finfish resources of freshwater, brackishwater and marine water in India

India is blessed with a wide species biodiversity in its natural waters that constitute more than 10% available fish species of the globe. Out of more than 30,000 fish species reported globally, Indian waters harbours 3035 species (1016 freshwater, 113 brackishwater and 1906 marine species) (DAHD&F, 2018), including 200 commercially important marine species and 291 exotic species (Annon, 2011). At present, breeding, seed production and grow-out technology have been standardized for more than two dozens of freshwater species, 7-8 brackishwater finfishes and 4-5 marine species.

The cyprinids are the major group of freshwater species cultured followed by the catfish. The cyprinid group mainly includes three Indian major carps, exotic carps, minor carps, barbs and many small indigenous species. In recent years, catfishes such as striped catfish, magur, singhi and pabda; and the air breathers such as murrels and climbing perch are emerging as potential species for aquaculture. Table-3 gives an account of the different species under the various groups and the present status of their seed production and grow-out culture in the country.

Table 3. List of commercially important finishes (for freshwater, brackishwater and marine water aquaculture)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Species</th>
<th>Scale of seed production</th>
<th>Status in culture system</th>
<th>Area of culture</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Freshwater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i)</td>
<td>Group-Carp, barbs and minows</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Catla (Catla catla)</td>
<td>Commercial scale</td>
<td>Wide spread</td>
<td>All over India</td>
</tr>
<tr>
<td>2.</td>
<td>Rohu (Labeo rohita)</td>
<td>Commercial scale</td>
<td>Wide spread</td>
<td>All over India</td>
</tr>
<tr>
<td>3.</td>
<td>Mrigal (Cirrhinus mrigala)</td>
<td>Commercial scale</td>
<td>Wide spread</td>
<td>All over India</td>
</tr>
<tr>
<td>4.</td>
<td>Silver carp (Hypophthalmichthys molitrix)</td>
<td>Commercial scale</td>
<td>Wide spread</td>
<td>All over India</td>
</tr>
<tr>
<td>5.</td>
<td>Grass carp (Ctenopharyngodon idella)</td>
<td>Commercial scale</td>
<td>Wide spread</td>
<td>All over India</td>
</tr>
<tr>
<td>6.</td>
<td>Common carp (Cyprinus carpio)</td>
<td>Commercial scale</td>
<td>Wide spread</td>
<td>All over India</td>
</tr>
<tr>
<td>7.</td>
<td>Fringed lipped carp (Labeo fimbriatus)</td>
<td>Commercial scale</td>
<td>Regional</td>
<td>Karnataka, Odisha</td>
</tr>
<tr>
<td>8.</td>
<td>Kurialabeo (Labeo gonius)</td>
<td>Commercial scale</td>
<td>Regional</td>
<td>North east</td>
</tr>
<tr>
<td>9.</td>
<td>Kalbasu (Labeo calbasu)</td>
<td>Commercial scale</td>
<td>Regional</td>
<td>All over India</td>
</tr>
<tr>
<td>10.</td>
<td>Bata (Labeo bata)</td>
<td>Commercial scale</td>
<td>Regional</td>
<td>West Bengal</td>
</tr>
<tr>
<td>11.</td>
<td>Reba (Cirrhinus reba)</td>
<td>Commercial scale</td>
<td>Regional</td>
<td>Assam, Odisha</td>
</tr>
<tr>
<td>12.</td>
<td>Pengba (Osteobrama belangeri)</td>
<td>Commercial scale</td>
<td>Regional</td>
<td>Manipur, West Bengal, Odisha</td>
</tr>
<tr>
<td></td>
<td><strong>Species</strong></td>
<td><strong>Scale</strong></td>
<td><strong>Location</strong></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>----------------------------------------------------</td>
<td>----------------</td>
<td>-------------------</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td><em>Semiplotus semiplotus</em></td>
<td>Regional</td>
<td>Arunachal Pradesh</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td><strong>Group- Catfishes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Mola (Amblyphtyngodon mola)</strong></td>
<td>Limited scale</td>
<td>Wide spread</td>
<td>Planes of India</td>
</tr>
<tr>
<td>(ii)</td>
<td><strong>Magur (Clarias magur)</strong></td>
<td>Commercial scale</td>
<td>Wide spread</td>
<td>All over India</td>
</tr>
<tr>
<td></td>
<td><strong>Singhi (Heteropneute fossilis)</strong></td>
<td>Commercial scale</td>
<td>Wide spread</td>
<td>All over India</td>
</tr>
<tr>
<td></td>
<td><strong>Pangus (Pangasiadan hypophthalmus)</strong></td>
<td>Commercial scale</td>
<td>Wide spread</td>
<td>All over India</td>
</tr>
<tr>
<td></td>
<td><strong>Butter catfish (Ompok pabda)</strong></td>
<td>Commercial scale</td>
<td>Regional</td>
<td>West Bengal, North east</td>
</tr>
<tr>
<td></td>
<td><strong>Butter catfish (Ompok bimaculatus)</strong></td>
<td>Commercial scale</td>
<td>Regional</td>
<td></td>
</tr>
<tr>
<td>(iii)</td>
<td><strong>Group- Other air breathers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Striped murrel (Channa stiata)</strong></td>
<td>Mass scale</td>
<td>Regional</td>
<td>Telengana, Andhra Pradesh, Odisha</td>
</tr>
<tr>
<td></td>
<td><strong>Koi (Anabas testudineus)</strong></td>
<td>Mass scale</td>
<td>Regional</td>
<td>Telengana, Andhra Pradesh, Odisha, West Bengal</td>
</tr>
<tr>
<td>(iv)</td>
<td><strong>Other important species</strong></td>
<td></td>
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<tr>
<td></td>
<td><strong>Giant freshwater prawn (Macrobrachium rosenbergii)</strong></td>
<td>Commercial</td>
<td>Limited scale</td>
<td>All over India</td>
</tr>
<tr>
<td></td>
<td><strong>Golden Mahseer (Tor putitora)</strong></td>
<td>Limited scale</td>
<td>Limited scale</td>
<td>Cold water</td>
</tr>
<tr>
<td>B.</td>
<td><strong>Cold water species</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td><strong>Snow trout (Schizothorax richardsonii)</strong></td>
<td>Limited scale</td>
<td>Limited scale</td>
<td>Cold water</td>
</tr>
<tr>
<td>C.</td>
<td><strong>Brackishwater</strong></td>
<td></td>
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<tr>
<td></td>
<td><strong>Grey mullet (Mugil cephalus)</strong></td>
<td>Limited scale</td>
<td>Limited scale</td>
<td>Kerala, West Bengal</td>
</tr>
<tr>
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<td><strong>Milk fish (Chanos chanos)</strong></td>
<td>Limited scale</td>
<td>Limited scale</td>
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<td></td>
<td><strong>Pearl spot (Etropus suratensis)</strong></td>
<td>Limited scale</td>
<td>Limited scale</td>
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<tr>
<td></td>
<td><strong>Ten pounder (Elops machnata)</strong></td>
<td>Limited scale</td>
<td>Limited scale</td>
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</tr>
<tr>
<td></td>
<td><strong>Sea bass (Lates calcarifer)</strong></td>
<td>Limited scale</td>
<td>Limited scale</td>
<td>Coastal states</td>
</tr>
<tr>
<td></td>
<td><strong>Indian white prawn (Penaeus indicus)</strong></td>
<td>Commercial scale</td>
<td>Limited scale</td>
<td>Coastal states</td>
</tr>
<tr>
<td></td>
<td><strong>Black tiger prawn (Penaeus monodon)</strong></td>
<td>Commercial scale</td>
<td>Wide spread</td>
<td>Coastal states</td>
</tr>
<tr>
<td></td>
<td><strong>Pacific white shrimp (Litopenaeus vanamei)</strong></td>
<td>Commercial scale</td>
<td>Wide spread</td>
<td>Coastal states</td>
</tr>
<tr>
<td></td>
<td><strong>Banana shrimp (Fenneropenaeus merguiensis)</strong></td>
<td>Limited scale</td>
<td>Limited scale</td>
<td>Tamilnadu</td>
</tr>
<tr>
<td>D.</td>
<td><strong>Marine species</strong></td>
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</tr>
<tr>
<td></td>
<td><strong>Pearl Oyster (Pinctada fucata)</strong></td>
<td>Traditional method</td>
<td></td>
<td>Kerala, Tamilnadu</td>
</tr>
<tr>
<td></td>
<td><strong>Green Mussel (Perna viridis)</strong></td>
<td>Traditional method</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Green Mussel (Perna indica)</strong></td>
<td>Traditional method</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Edible oyster (Crassostrea madrasensis)</strong></td>
<td>Traditional method</td>
<td></td>
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</tbody>
</table>
Prospects of commercially important finfish aquaculture

Freshwater aquaculture

The R&D activities in the freshwater fish farming over the last five decades has enabled the freshwater aquaculture as an enterprise that can be adopted (i) in varied scale of operation from traditional farming to intensive culture, (ii) for varied stages from hatchery operation to fry/fingerling/stunted fingerling production or grow-out farming, (iii) for varied groups and species as per the regional demand, (iv) can fit to varied time scale (short and long term) and also (v) as per lending capacity of the operator. Several other sub-enterprises such as marketing, processing industries, cold chain facility, etc. are directly and indirectly associated with the sector which provide income avenues for a large number people.

At present, India has a huge domestic demand and supply gap in the freshwater fish. Further, the population growth and continuous shift in the food habit oriented towards fish as a safe nutrients source are more likely to widen the demand supply gap in the coming years. The present production of inland aquaculture comes from approximately 70% of the available 2.41 million ha of ponds and tanks resource. This indicates that there is a large scope for horizontal expansion of the culture sector. Similarly, while the national average of fish productivity is 3.0 t/ha, a production level of 5-6 t/ha has been commonly achieved in the ponds which further indicates the scope to increase the vertical productivity.

Cyprinids form the most important group contributing more than 82.3% of the total culture production (Fisheries Handbook, 2019). Among the cyprinids, 81.4% contributed by the three species of Indian major carps (catla, rohu and mrigal), 10.5% by the three domesticated exotic carps (silver carp, grass carp and common carp) and 8.1% by the minor carps. Therefore, substituting the entire carp component from the culture system is a remote possibility. Apart from monoculture in limited area, large scale culture of any new species would largely depend on its compatibility with the major carps and their performance in the grow-out system. Attempts to diversify aquaculture system during last two decades have shown enough possibilities to incorporate more than two dozen of species into freshwater culture system. These include the groups like minor carps, barbs, catfishes, murrels, freshwater prawn, etc, which have registered their increasing popularity among the fish farming communities. Further, successful developments of mass scale seed production technologies have paved the way for culture of these species.
Brackishwater aquaculture

The brackishwater farming till recent years is confined to farming of few shrimp species and mostly oriented towards export market. Tiger shrimp *Penaeus monodon* was the main species cultured in the 90s. After the setback in tiger shrimp culture due to white spot disease, most of the shrimp ponds remained unutilized. A section of these ponds were utilized for culture of finfishes depending on the seed collected from wild. Later, owing to the non-availability of Specific Pathogen Free (SPF) stock of the native penaiids, *Litopenaeus vannamei*, an exotic shrimp has been introduced during 2005-2009. Its culture not only revived the shrimp culture industry, but also its huge production has pushed the shrimp farming to a new height with a production of 0.622 MMT in 2018-19 compared to 0.05769 MMT of *Penaeus monodon* (MPEDA website visited in January, 2019). The other shrimp species cultured to a limited extent includes Indian white prawn, *Penaeus indicus*. But there has the potential for commercial cultivation of at least 8 species of finfish and two species of crab (CIBA, 2017).

Culture of finfishes in brackishwater area has been in a low profile and wherever it was practiced, it was relying on the seed collected from the natural waters. While the finfish species being cultivated are seabass (*Lates calcarifer*), mullets (*Mugil cephalus*), pearlspot (*Etroplus suratensis*), milkfish (*Chanos chanos*) and cobia (*Rachycentron canadum*). Non-availability of assured seed supply of these species is posing major bottleneck for expansion of their culture area. At least ten species of shrimp, eight species of finfish and two species of crab have been identified by ICAR-CIBA to have potential for commercial cultivation (CIBA, 2017). With the success in closing the life cycles and development of mass-scale seed production technology in sea bass, milkfish and pearl spot, newer avenues are being created for large-scale farming of these species in the brackishwater sector.

Besides the finfishes, breeding and culture of brackishwater ornamental fish has been identified as one of the most profitable venture. While many important indigenous ornamental species have been successfully cultured and traded at commercial level, efforts are on to breed more species of demand. Crab fattening has been promoted as another important avenue for the small to marginal farmers and Self Help Groups (SHGs). Apart from the sea farming, bivalves and seaweeds have been cultured in the shrimp ponds along with the shrimps. Species like cobia and seabass have been identified as potential species for sport fishing to promote aqua-tourism. The concept of multi-trophic aquaculture (MTA) has been peaking up in the brackishwater
sector as a move towards diversification, which would ensure diversification of the sector with increased productivity, income and environmental upkeep.

**Mariculture**

Globally, mariculture has been playing major role in increasing the seafood production in the face of growing demand for marine protein. Development in marine fish farming activities in the country was initiated by the ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI) in early 1980s leading to the initiation of small scale commercial practices by 1990s. The Marine Product Export Development Authority (MPEDA) and the National Institute of Ocean Technology (NIOT) also have contributed significantly towards the development. Realizing the need to increase fish production and to tap the huge potential of marine farming, the ICAR-CMFRI has stressed on standardizing seed production and farming techniques for at least two dozen high valued marine finfish in next ten years. The technologies for seed production and grow-out culture of cobia (*Rachycentron canadum*), groupers (*Epinephelus* spp) and pompano (*Trachynotus blochii*) have been developed and demonstrated, while efforts are on to bring more promising species under farming. In recent years, lots of emphasis is being given on cages farming of these species in sea. Successful demonstration of cage farming of cobia, sea bass, groupers and pompano along the Indian coasts has opened up scope for bring up more candidate species in mariculture in coming years. Besides the food fish, breeding and seed production of many important marine ornamental fishes has already been developed by ICAR-CMFRI and ICAR-CIBA.

Recognizing the potential of the fisheries sector, the Government of India has launched the ‘Blue Revolution’ for the second time in the country. The DAHD&F has prepared a detailed Integrated National Fisheries Action Plan-2016 targeting total fish production at 15 MMT by 2019-20. The action plan envisaged different targets (DAHD&F, 2019):

- Increasing the inland fish production to 10.89 MMT by 2020-21
- 24% increase in productivity from the pond culture
- Enhanced focus on creation of infrastructure for sustainable growth
- Connecting 15 million beneficiaries for livelihood opportunities
- Development of post-harvest technology to reduce waste up to 10%
- Increased market acceptability to the consumers
- Increasing the export by more than 30%
All states have been asked to prepare State Action Plan for 5 years. In 2019, a separate department named Department of Fisheries has been created by Government of India under the Ministry of Fisheries, Animal Husbandry & Dairying for the focused development of the fisheries and aquaculture sector of the country.

**Present hatchery production, seed rearing and aquaculture practices and production of commercially important finishes**

**Freshwater aquaculture sector**

**Hatchery establishment for seed production**

The success in induced breeding of Indian major carps in 1957 was followed by a sequel of activities over the last five decades that includes ampouling of the pituitary extract, refinement of breeding protocol, evolution of hatchery technologies and hatchery models from the initial earthen pits to the latest circular eco-hatchery model, use of synthetic inducing agents and better broodstock management techniques, etc. The easy availability of synthetic hormone formulations like Ovaprim, Ovatide and WOVA-FH in 1990s have revolutionized carps seed production through improvement in spawning success, fertilization, hatching and spawn survival. At present more than 2000 carp hatcheries are operating and the country is self-sufficient in carp fry production. The eco-hatchery model is by far the most commonly used design for seed production of major carps. The same model has also been used for seed production of the minor carps and barbs. Use of FRP hatcheries, the portable version of the eco-hatchery model, has helped in seed production in remote and difficult areas. With species diversification and introduction of newer species into the culture system, more specialized hatchery systems have been developed for seed production in commercial scale for different species of catfishes (magur, striped catfish, pabda, etc.), freshwater prawn, murrels, etc. However, the number of hatchery operating at present for the non-carp species is limited, but expected to increase considering the present impetus given to aquaculture diversification process in the country.

Production of quality seed for the sector has been given importance to harness the production potential of different species through adoption of selective breeding and milt cryo-preservation technologies. The revolutionary success of selectively bred rohu ‘Jayanti’ with higher genetic gain that led to realize higher growth in every successive generation and increase the production has paved the way for expansion of the technique to other species like catla and freshwater prawn. Further, there has been improvement in the protocols for the brood stock maintenance and induced
breeding of the major carps. Use of specialized brood stock diets like CIFABROOD™ is bringing early maturity in carps. The same carp brood fish have been bred 2-3 times (multiple breeding) through stretching the breeding season using improved brood stock maintenance protocol. The technology of multiple breeding of carps could demonstrate 2-3 fold higher spawn recovery over conventional single breeding during a season.

In brackishwater sector, with the boom in tiger shrimp farming, large number of hatcheries were being established in the coastal states for seed production. But later, most of them remained non-functional due to the setback because of widespread white spot disease in prawn farming. With popularization of Pacific white shrimp, most of these hatcheries were revived for its seed production besides coming up of new hatcheries. Seed production technologies have been standardized for few promising finfishes and the list includes sea bass (*Lates calcarifer*), grey mullets (*Mugil cephalus*), milkfish (*Chanos chanos*), pearlspot (*Etroplus suratensis*), etc. Polyculture technology of these fishes has been demonstrated to small scale farmers, which have triggered the diversification in the brackishwater aquaculture system.

The seed production technology has been developed for a number of marine finfishes. The list includes cobia (*Rachycentron canadum*), pompano (*Trachynotus blochii*), sea bass (*Lates calcarifer*), groupers (*Epinephelus* spp.), snappers, breams and number of ornamental fishes.

### Seed rearing

Over the years, lot of research efforts are made to improve the seed (fry and fingerling) production protocols of the freshwater fishes including carp, with regard to standardization of effective stocking density, supplementary feeding, use of inputs and pond management protocol, etc. Besides using earthen ponds for large scale carp seed production, technologies have been developed for high density seed rearing in large concrete tanks with more than 50% survival from spawn to fry, even at 2000 spawn/m² density (Das et al., 2015) and more than 80% survival from fry to fingerling (Pawar et al, 2009; Jena et al, 2011). Use of such concrete tanks also ensures taking at least three crops of nursery rearing (15 days each). Concrete tanks are also being used for the in-door and out-door rearing of initial life stages (fry and fingerling) of other non-carp species such as catfishes, murrels and koi with higher seed survival. The fry production in the country has increased to 50.252 billion (Fig. 2) fulfilling the requirement of culture sector. But attempt to develop culture based capture fisheries in open waters has raised the total seed requirement in ponds and reservoirs further to about 60.0 billion fry, creating seed deficit again.
Although fingerlings are considered as the ideal stocking material for grow-out fish culture, lack of motivation among the farmers for fingerling raising and inadequate pond availability are main constrains. As a result, most of the farmers use fry as stocking material for aquaculture, leading to poor survival, improper stocking density and poor production. Emphasis has been given in recent years in increasing awareness on the benefit of stocking larger seeds such as fingerlings and stunted juveniles. Underlining the importance of fingerling stocking as a key to increase fish production, many State Fisheries Departments have brought promotional schemes that has helped to inverse fingerling availability. A National Freshwater Fish Brood Bank (NFFBB) has been established for production and supply of good quality brooders to improve the seed quality. The National Fisheries Development Board (NFDB) has launched a major programme ‘Mission Fingerling’ to promote the fingerling production which is expected to change the fish seed scenario in the coming years. Use of stunted fingerling for grow-out stocking has become popular among the farmers. Stocking of fry in high density and sub-optimal feeding are the two key features of stunted seed production. The crowding stress and limited nutrition restrict the growth of these seed. Production of such stunted juvenile seed is particularly essential and proven to be beneficial for the practice of multiple-stocking and multiple-harvest (MSMH) cropping pattern or use multiple cropping in a year. Although the compensatory growth of the stunted seed has not been observed in carps in subsequent grow-out phase (Das et al., 2016), farmers prefer to stock these larger seed to
get higher survival, faster growth and increased yield. There were generally two tiers of seed farmers in the freshwater farming sector who practiced fry rearing and fingerling rearing. Popularization of stunted seed has given rise to a third tier of seed producer to produce stunted juveniles for grow-out stocking. This profession has been proved to be economically viable and has been adopted by some farmers as full time profession.

**Grow-out practices**

Several combinations of culture practices are in vogue in the country suiting to the need of water resources, preferred fish species, availability of feed resources, etc. and also the investment potentials of the farmers. With an understanding of the biological basis of fish production, carp culture has undergone several changes, which can be categorized as low, medium and high input technologies.

The low-input or extensive system relies on the principle of promoting the natural fish food organism and utilizing the same by the fish feeding at the base of the food chain, *viz.*,, phytoplankton, aquatic weeds and detritus, etc. Use of limited input such as manures and fertilizers in this system often leads to 1.5-2.0 t/ha/year yield. Such system with additional use of supplementary feed in limited quantity under the extensive farming practice increases the yield level further to 2.0-3.0 t/ha/yr. The medium input system involves the semi-intensive method where the ponds are stocked with appropriate seed density, fed with supplementary feed and maintained with good water quality. Composite culture of Indian major carps with the exotic silver carp, grass carp and common carp is a good example where the latter group utilizes the abundant natural productivity with a far greater output than the Indian carps. While production level of 4-5 t/ha of carps has become easily achievable with adoption of the basic fish farming technology in such system. Many farmers realize 7-8 t/ha yield level with use of sinking and extruded floating pellet feed.

The high-input system of carp culture in India is known to be a conglomeration of semi-intensive and intensive systems. Such system makes use of quality seed, fertilizers, balance feed, aeration and occasional water exchange or replenishments. While use of the medium input semi-intensive system was the practice in most of the freshwater ponds till recent years, use of aeration, extruded floating pellet feed and water exchange are added off late in the system. This has made possible to produce higher fish yield to the tune of 8-10 t/ha in several fish farms. Production levels of over 15 t/ha/yr have been reported by adoption of this high-input technology (Tripathi et al, 2000).
The crop period of grow-out carp farming usually extends up to one year within which, the stocked fingerlings grow to marketable size. The productivity of such ponds usually remains underutilized during the initial phase since fish biomass remains much below the carrying capacity in this phase. Efforts have been made to utilize the pond more effectively, especially during the initial six months of carp farming, for which different cropping patterns like single stock (more density)-multiple harvest (SSMH), multiple stock multiple harvest (MSMH) and multiple cropping (MC) have been developed. All these changes in cropping pattern realization of higher yield compared to the conventional single stocking-single harvest (SSSH) method of farming (Das et al., 2019). Now a day, the commercial fish farming is gradually being transformed to a ‘fish fattening process’ where the stocking size ranges up to 400 g and crop duration is shortened to four months to produce the marketable size. Inter-cropping of minor carps (for the initial six months culture) in the major carp polyculture system has also been proven to yield 21-28% higher yield. All these cropping patterns not only yield better, but also increase the investment capacity of the farmers through scope of interim harvest, ensure plough-back of investment and reduce the risk for the investment. Though major carp farming is indispensable system in our country, its profit margin can be further increased through inclusion of compatible high valued fishes belonging to the small and large catfish groups, murrel and freshwater prawn. Further, technologies have also been developed for monoculture of the latter groups yielding high profit margin. Increasing species spectrum in the culture system therefore have been emphasized in recent years for increasing the production and farm income, and widening the consumer’s choice with species conservation as the secondary objectives.

The aquaculture in wastewater is another form of non-conventional farming system used in several pockets of the country. The sewage-fed aquaculture practiced in West Bengal is an activity long practiced for utilization of the wastewater for fish production. The duck-weed based waste water treatment system is a good example of conversion of waste energy into fish protein while ensuring treatment of sewage prior to disposal to open waters. With stocking of 5000-10000 carps fingerlings/ha, fish production from such system have reached at 3.7-5.2 t/ha/yr (Sahoo et al., 2012).

Paddy-cum-fish farming is another form of non-conventional farming method with the basic principle similar to the integrated farming models. Such methods are mostly used in the low land area where rice is the only crop grown once in a year. Compatible components selected for incorporation in such system has proven yield improvement, efficient resource utilization and
increased farm income. The rice-fish system is popular farming practice in the north eastern states of the country and few parts of Kerala in the south.

In recent years there is a paradigm shift in the choice of consumers to opt for safe and quality food, even if it taxes higher price on them. Recognizing organic aquaculture as one of the thrust area, few farmers in recent years are coming forward for the organic fish farming through utilization of simple traditional culture techniques and involving natural inputs; and simultaneously ensuring management and conservation of the natural resource base.

Effort to improve fish production in natural water bodies in recent years has increased the importance of cage and pen culture. These are the systems that provide scope for fish production through utilization of open waters like reservoirs where the natural fish population has otherwise remained subdued. In recent years, many State Fisheries Departments with support from the National Fisheries Development Board (NFDB) have promoted large-scale cage farming in reservoirs and as such it is linked to the livelihood of the local fishermen society. Similarly, the pen culture technology has the potential to be adopted in the floodplain wetlands of Bihar, Assam and West Bengal.

**Brackishwater sector**

Despite the periodic setback due to emergence of disease outbreaks, the prawn farming sector in the country has been thriving with certain measures like change in the cropping pattern, cultured species, declaration of fallow period, crop rotation with finfish and prawn, reduction of stocking density, reduction of salinity levels etc. Farming of finfishes in brackishwater pond has been stressed upon after the periodic setback in shrimp farming. With closure of life cycle in species like sea bass, grey mullet, milk fish and pearl spot, culture of these species are now picking up. Though traditional, semi-intensive and intensive methods are practiced for shrimp farming, the finfish farming is yet carried out in low scale either under polyculture with shrimp or during the fallow period. Inadequacy in seed of these finfishes in commercial scale has been the major constrain for its expansion.

**Mariculture sector**

Fish production from the marine sector in India comes almost entirely from the capture fisheries despite having the huge potential for sea farming. Unlike other South Asian countries, sea farming in the country has long been confined to culture of see weeds, pearl oysters, edible oysters and mussel in a few patches of the southwest coast. The country has not made major
headway till the end of last century in finfish farming, mainly due to dependence on natural seed collection and non-availability of assured seed supply from hatchery technology. But, standardization of seed production of important marine finfishes has created impetus for diversifying the marine aquaculture. At present, cage culture demonstration is underway in both west and east coasts of the country with installation of over 750 cages. It is anticipated that with the availability of favourable policy guidelines for utilization of coastal waters and increased private investments, the culture would expand further in coming days.

Seaweed farming is another avenue that has not yet reached its full potential, despite having standardized farming technologies for many species, good resources and heavy demand from the industry. The increased demand of seaweeds by the pharmaceutical and food industry has paved the way for expansion of the culture area. Modification of the various culture systems aimed at augmenting the production of edible and pearl oyster has been a regular activity of the marine researchers. Efforts are on to utilize the concept of multi-trophic aquaculture activity to increase the seafood production. Production of marine ornamental fish is another area with enormous potential to tap the export market. A lot of emphasis is being given now-a-days to develop the breeding and seed production technology for the high valued ornamental fish. Sea farming of edible oyster has been accepted as popular mariculture technologies by the coastal communities in the south west coast. Further, while edible oyster farming is well-established in the three main estuaries viz., Ashtamudi, Kayamkulam and Vembanad of Kerala coast, it has great potential for expansion to other maritime states, viz., Karnataka, Goa, Maharashtra, Tamil Nadu, Puducherry and Andhra Pradesh. The acceptance of mussel farming (green mussel, *Perna viridis*, brown mussel, *P. indicus*) as a mariculture activity for part time avocation is in vogue since the last two decades in the coastal villages in southwest coast, and today over 20,000 t of mussel are being produced only from Kerala.

The country is one of the major producers of seaweed from the traditional farming in the coastal waters which caters to the requirement of food industry, pharmaceutical and marine biomolecule production. The species cultured includes *Gelidiella acerosa*, *Gracilaria edulis*, *Hypneamus ciformis*, *Acanthophorhas picifera*, etc. Oyster, both pearl producing and edible, form other important cultured species in the marine sector. The country is already having a well-organized marine pearl production chain with culture of several *Pinctada* species. The edible Indian backwater oyster, *Crassostrea madrasensis* extensively farmed along the south Indian coast. Similarly, marine mussels is a preferred group of shellfish cultured in the Indian coast
and includes species like green mussel, *Perna viridis* and the brown mussel *P. indicus*.

**Issues and challenges**

The success of the aquaculture sector largely needs an approach for balanced utilization of the land, labour, water and other resources. The diminishing per capita land holding, growing water scarcity, increased competition from other production entity for inputs, increasing labour cost are some of the major constraints that affect aquaculture sector.

**Environmental issues**

**Lack of regulated development**

Fish farming in ponds and tanks until recent years had been a freelance activity in India with no observation of systematic protocols and procedures, often oriented towards profit making. Unscrupulous use of chemicals and antibiotics are in vogue with little concerns about ecological consequence and food chain perturbation. Improper management and disruption of natural natality and mortality in open waters has disturbed the natural bio-resources. These open waters often serve as the natural source of brood stock for strengthening the gene pole and ensure quality seed production. Unfortunately, many of these open waters are overexploited, losing the precious natural stock or contaminated with hatchery bred population. Lack of regulation for the hatcheries paved the way for improper use of brood stocks leading to problems of inbreeding and hybridization, severely degrading the seed quality.

**Water scarcity**

India with 2.4% land area and 4.2% of the water resources of the world, is sustaining 17.74% of World population (India population, 2018) and 15% of livestock. The total utilizable water available in the country constitute 690 billion cubic meter (BCM) from surface water resources and 433 BCM from ground water resources, adding up to only 1,123 BCM (India-WRIS, 2012). The per capita water availability per year in India has been declining years after years from 5178 m$^3$ in 1951 through 2210, 1829 and 1544 m$^3$ in 1991, 2001 and 2011, respectively, and estimated to be 1421 m$^3$ by 2021 (CSO, 2018). India has already reached to a ‘water stressed’ situation since 2015, as per the international norms which has categorized country with less than 1700 m$^3$ per capita per year as ‘water stressed’ and less than 1000 m$^3$ per capita per year as ‘water scarce’ (India-WRIS, 2019). Against declining water availability, our
gross irrigated area needs to be increased to ensure increased food grain production of 450 to 500 mmt to feed the 1620 million population by 2050. The water requirement from livestock sector is also expected to increase. Further, there has been shrinkage of water table, frequent drought situation, changes in climatic and rainfall pattern which are important particularly in context of fish farming. Although the consumptive water use is low, the total water requirement is high for freshwater aquaculture and adequate quantity of quality water is a prime requisite. In such situation, increasing aquaculture production in the country through competition for water share with agriculture and allied sectors is going to be the most important challenge in the future. Research has been initiated on water budgeting and increasing water use efficiency in the aquaculture sector, where judicious use and reuse of water is being emphasized.

Climate change

Almost all the pond resources in the country are rain-fed and largely depend on the timely arrival of the monsoon and good rainfall during the season. But, erratic monsoon and deficient rainfall have hit the aquaculture sector during the previous year’s leading to drought and flood situations, both of which are undesirable for aquaculture. Shifting of the breeding season has already been experienced in major freshwater cultured species due to the climate change effect. Similarly alterations in other sensitive water quality parameters such as ammonia, air and water temperature would have pronounced effect on the breeding behavior, feed utilization efficiency, growth and even on the sensory qualities of the cultured fish species. The increased ambient water temperature due to global warming would increase the risk of disease occurrences spread by vectors. Thus, climate change is going to be major future challenge to increase fish production from aquaculture.

Introduction of alien species

Conservation of fish biodiversity is an important responsibility for ecological balance in the natural water as well as for maintaining the genetic variability of the stock for future use. Introduction of new species many a times disturbs the ecosystem balance. Alien species have emerged as a major concern for the aquaculture sector due to porous border of the country. Though certain species like *Pangasianodon hypophthalmus* and *Piractus brachypomus* are doing well in the culture system improving the pond productivity, lesson learnt from introduction of African catfish *Clarias gariepinus* and accidental entry of the sucker mouth fish (devil fish or *Hypostomus plecostomus*) warrants the need of cautious approach in introducing newer species in to our ponds.
Slow pace of horizontal expansion

Allocation of agricultural land for aquaculture purpose has limited scope as there is increasing need of the food grain production in the country. Higher initial capital requirement for aquaculture farm construction is the other deterrent for the horizontal expansion. Though more than 30% of tank/ponds resources in the country are yet remained underutilized/unutilized, expanding aquaculture activity to these resources would need additional inputs from the pole of input resources for which there are many competitors. In case of community owned ponds/tanks, uniform leasing policy for water bodies as well as large water sheets is non-existent in most of the states. While some of the states lease water bodies for a long duration of 5-10 years, the leasing period in most others are only for one to two years. Short-term leasing policy is always disadvantageous for the resource since the leasee would try to exploit the maximum benefit out of it without giving a thought for its maintenance and long term preservation.

Resource characteristics and allocation

Due to rain fed nature of most of the pond resources in freshwater sector, many do not hold the water depth required for fish farming throughout the year. Further, an erratic or reduced rainfall increases the risk of drying up or critical reduction in water depth often leading to premature crop harvest and less profit. Large community owned ponds form a major chunk of the potential pond resources. These ponds have inherent social and ownership problems that hinder scientific fish farming, which often remain restricted to only seed stocking and without much management. Higher pond renovation cost is a usual deterrent for the farmers to do so. Resource renovation has been included in recent years as integral part in various schemes launched by State Fisheries Departments, which is expected to yield good dividend.

The general tendency of the farmer to use pond for grow-out purpose, despite varied depth, often leads to their in-effective use, especially for the shallow ponds. But shallow ponds can more effectively be utilized for seed rearing with higher profit margin rather than its use for grow-out purpose. Though there is an all-time heavy demand for fingerlings in the sector, only few farmers plunge into the seed production business. This indicates lack of awareness among the farmers lead to improper allocation of the resources. Therefore, allocating the resources for the suitable intervention (seed rearing, yearling rearing or grow-out purpose) can play a key role for rational supply of the different life stages of the fishes which can promote the grow-out production.
Inadequate seed availability

The country at present produces 52.3 billion of fry mostly of carps and is considered self-sufficient. But, the fingerling production process is often marred with shortage of rearing space, reluctance for the higher investment, besides the problem of long distance transportation. As a result, fingerling availability has remained as a constraint and most ponds are stocked with seed at fry stage. While assured and easy availability of good quality fish seed is important, the seed production at present in freshwater sector is dispersed and in most case, does not comply to the prescribed technology, often leading to the production of poor quality seed. In this context, ‘Cluster seed production approach’ can be a good proposition for an effective technology back up and to produce quality seed. Underlining the importance of fingerling stocking, ‘Mission Fingerling’ has been launched by NFDB. Similarly, the State Fisheries Departments are also promoting fingerling production through various promotional schemes.

Poor seed quality

The freshwater fish seed production has been an unregulated activity and lacks hatchery accreditation and seed certification system. While “Seed testing and certifying laboratory” established in few countries for monitoring the genetic purity of seed. Such provision is non-existent in India except in the brackishwater shrimp. As a result, in many hatcheries, captive breeding of same population over the years has led to poor genetic base often leading to inbreeding depression, retarded growth, poor disease resistance and severe quality degradation of seed throughout the country. Besides, large scale hybridization has been in practice as many hatcheries do not comply with the required facilities for brood stock maintenance. Hatchery accreditation and seed certification are earnestly required to ensure the seed quality and its traceability, the latter being increasingly stressed now days. In this regard, while devising a centralized hatchery accreditation and seed certification mechanism is in the pipeline. Some State Governments have already come up with their certification mechanism. Such efforts should be replicated in all the States for a sustainable up keeping of the gene pool of the various cultivable species.

Limited use of supplementary nutrition

Realization of higher biomass yield with use of supplementary feed in carp farming is a well-known fact. But, the use of supplementary feed is not yet flourished in the carp farming sector, mostly due to inadequate awareness on its benefit and reluctance among the farmers for the investment. Despite the
availability of commercial feed (sinking and floating pellets) in large scale, its use is yet mostly restricted to the shrimp farming. Few progressive farmers are engaged in commercial aquaculture activity with the use of feed for major carps, catfishes and freshwater prawn.

Despite the various constrains, the aquaculture feed industry has witnessed an exponential growth due to growing consumption of seafood and growth of aquaculture industry in last decades. The aquaculture sector is currently using about 20% of total available concentrate feeds in the country. The market size of aqua-feed has reached USD 1.2 billion in 2017 and expected to reach USD 2.3 billion in 2023 (Annon, 2018). The total installed capacity of feed mills for shrimp feed production in India was about 1.6 MMT from 30 manufacturing plants. About 0.75 MMT of shrimp feed and roughly equal quantities of freshwater fish feed were produced in 2016 (Ambasankar et al., 2017). The demand is further expected to rise as unfed or mash-fed carp farms are gradually shifting to use of pelleted feeds, and there is an increase in the culture area. Further, concept of contract farming, where farmers are provided with the required fish feed, is becoming the key drivers to increase demand for feed. Therefore, sustenance and further expansion of the aquaculture activity needs promotion of the production of concentrated feed rather than relying on the conventional feed mixture. While promoting establishment of feed mill, efforts should also be made to encourage finding alternate ingredients.

**Low key of health care**

Health management during culture has been at low key in the country barring the preventive measures like use of lime and few chemicals. Only the outbreak of fish epidemics like EUS is attended by the farmers. The other health problems as well as poor growth and mortality due to water quality issues are often ignored in culture ponds. However, intensification of the aquaculture practice in recent years has increased the incidence of disease and at the same time awareness for the loss due to disease has increased. In a study on crop loss due to argulosis, Sahoo et al (2013) have assessed the loss to be Rs. 30,000/ha. Disease surveillance has been stressed upon now a day to address the emerging pathogenic problems and their control. Remedies in the form of prevention through scientific inputs and environmental management, development of disease diagnostic tools, therapeutics for control of infection, immuno-stimulants, chemical formulation etc. have been the key developments during recent years, which are expected to support the aquaculture sector in the wake of any disease threat.
Social issues

Low skill level and inadequate reach of the technology

Farming of fish in India has been elevated from a stage of home stead activity to a promising venture that can support as a full time profession. Over the years, effort has been given to increase the skill level and technical efficiency of the humane resource engaged in the aquaculture and fishery sector. But barring few progressive farmers, the freshwater farming is yet carried out as an ad-hoc activity by most farmers. Disperse nature of pond resources and poor education among the farming community are the other factors hindering easy access and adoption of technology, effective communication and learning. As a result, major portion of the resources is yet being under-utilized following traditional and extensive system with no systematic stocking density, species ratio and supplementary feed. The productivity of these ponds remain untapped and fish production remains low. Creation of human resource in aquaculture has been a continuous process supporting the culture sector. Fish farming has been demonstrated throughout the country through a vast network of 429 freshwater Fish Farmers Development agencies (FFDA) and 39 brackishwater Fish Farmers Development agencies (BFDA) covering 0.83 million ha water area. A total of 0.96 million farmers have been trained so far for fish farming by FFDA (DAHD&F, 2016-17). An Annual Action Plan for Skill Development in the Fisheries sector was being prepared and launched in 2017-18 to impart training to around 25000 stakeholders engaged at various levels of the production chain. However, experience over last few years reveals many of the trainees not venturing into the profession, the most important reason being the financial constraint, absence of crop insurance and the lack of entrepreneurship attitude for adopting fish farming as a full time profession.

Planning and management issues

Aquaculture and fisheries are included in the State subject. The inland sector is by and large in the domain of the State administration fully, while marine fisheries sector is shared responsibility of the Central and coastal State Governments. The success of the “Blue Revolution” lies with the effective planning and implementation of development programme with active participation of the States. With convergence of many centrally sponsored schemes such as Mahatma Gandhi Rural Employment Guarantee Act (MNREGA) Rastriya Krishi Vikas Yojana (RKVY), the States have prepared action plans for aquaculture development. However, such planning often faces few challenges, which need to be addressed for effective progress.
Non-availability of database

Due to the dispersed nature and difficult access of freshwater resources in the country, development of a strong data base has been a continuous problem. Further, majority of the ponds and tanks in the country belong to the private ownership and fish production data from these ponds are usually goes unaccounted. Similar is the case for ownership of the community tanks and minor irrigation projects. Non-availability of physical and social information on the resources has always hindered effective planning and also in the implementation of the various development schemes brought to the sector.

Lack of infrastructure and market facilities

Required infrastructure support promotes the aquaculture activity and plays key role to accelerate the development. Non-availability of suitable communication hinders input supply as well as marketing the produce. Almost total quantity of fish produced in the country today are either marketed in live/fresh condition in local market or carried long distance to other state. Governmental regulation and control over the domestic marketing system for the aquaculture produce are almost non-existent and thus, the price of the produce is influenced mainly by the demand and supply, for which the farmers often do not get their due price. Fish is a highly perishable commodity and needs an organized cold chain and quick delivery system from the farm gate to the consumers to maintain the quality and hygiene. Therefore, it requires storage facilities, ice plants, cold chains, roads and transportation in identified aquaculture areas to provide quality fish to the consumer. While availability of these infrastructures are negligible at present in the sector, adequate governmental investments required for creation of other facilities such as feed mills and ancillary industries (aerators, feed dispensers), organized hygienic market, post-harvest fish processing factories, etc. Development of infrastructure all along this cold chain would not only secure and increase the profit margin of the producer, but also would support excellent employment opportunity at every stage of the cold chain.

Increasing fish production is intrinsically related to the strategy to increase the popularity of fish. Popularity of processed fish products such as fillets, chunks, sticks and many other value added products in supermarkets is a new avenue for the freshwater sector to explore. Processing waste constitute nearly 40% of the freshwater fish which usually goes unused. But technology has been developed to utilize this waste for production of silage and high grade nutrient concentrate that can be used to fertilize agriculture crop as well as pond to boost productivity. This would significantly reduce the post-
harvest loss. Establishment of processing industry for production of these values added products would develop the economy of the sector besides creating the employment opportunity.

**Inadequate financial support and crop insurance**

The requirement of high capital investment to start an aquaculture farm often acts as a deterrent for entrepreneurs to venture into this business. Although many State Governments have initiated schemes to support fish culture projects, those are often insufficient. Involvement of the financial institutions for the aquaculture has been abysmally low especially for the resource poor farmers. Only vertical increase in the productivity of culture pond cannot cater to the fish demand in coming years and there exists a need of horizontal expansion of culture area for which financial support mechanism is required to establish new farm. Fortunately, many government support schemes have been extended and are being implemented to create new water bodies with an aim for water harvesting and fish production in the system together. Providing insurance coverage to the aquaculture crop is another important supporting factor for the development. The brackishwater prawn farming was widely supported by insurance companies in its boom time in the mid-1990s. But due to the incidence of disease outbreak, all these supports gradually faded away from the sector. Since freshwater aquaculture is subjected to many natural calamity (flood, drought, disease incidence, etc.), insurance coverage of the crop is earnestly required to bridge the protection gap. No insurance coverage increases the risk of investment in fish farming. A secure crop would attract investor to this sector and therefore introduction of the insurance scheme for aquaculture crop would help the development process.

**Issues related to export of aquaculture products**

At present, more than 50 different types of fish and shellfish products, mostly brackishwater and marine species, are being exported from India to 75 countries around the globe. During 2015-16, fish and shellfish products has emerged as the largest group in agriculture export to earn foreign exchange worth 451.07 billion INR from export of 13.77 lakh ton products. This constituted 10% of the total export and nearly 20% of the agricultural export of the country. However, fish produced from the freshwater sector in India has not yet reached an effective export market unlike other south-east Asian countries. Although marine fish and prawn products and shrimp from brackishwater culture sector from India have a strong presence in the export market, it is almost negligible in freshwater fishes. While an effective
planning, infrastructure and financial support can facilitate development of export oriented freshwater fish production system with stringent quality control measures, the advantage of the strong information technology can be utilized to support the product promotion and formulation of appropriate marketing strategies as per needs of the international markets.

**Institutional set up and stakeholder involvement**

Fisheries sector had drawn the attention of planners starting from the first five year plan and its share in the total as well as the agricultural outlay has increased in the subsequent five year plans. The development in the sector came in the form of investment in establishing more research Institutes and creation of State Fisheries Department. While the State Fisheries Departments have contributed greatly to the promotion of aquaculture development, the research spearheaded by the Indian Council of Agricultural Research (ICAR) since its establishment in 1929 played the vital role in the agricultural research and human resource development in the country through a network of Research Institutes, fisheries colleges under the State Agriculture Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras. The Department acted as the major link between the research Institutes and the farmers’ fields through a network. Fish Farmers Development Agencies were established in freshwater (FFDA) and brackishwater (BFDA) for demonstration of the various technologies, training and financial assistance to the farmers which has helped to bring revolution in the fish farming sector. Planned outlay for fisheries sector constituted many central, centrally sponsored and state sponsored schemes which have been implemented in the sector for the overall development. Table 4 shows the overall outlay and expenditure of the sector during the five year plans.

Fish production in the country as on today either from the fisheries or from aquaculture sector has been the outcome of the holistic participation of the farmers, entrepreneurs and others associated with the production chain, Fisheries Departments of various States, Central Government’s Ministries, Research Institutes, government and non-government organisations, financial Institutions, etc. who have worked coherently with a strong support from various centrally and state supported schemes. Apart from DARE, the Department of Animal Husbandry, Dairying and Fisheries (DAHD&F) and the Department of Agricultural Co-Operation & Farmers Welfare under the same Ministry were responsible for the development. The important organizations/Institutes working under the DAHD&F towards this cause are the Fishery Survey of India (FSI) having seagoing facilities and helps in fish stock assessment research, the Central Institute of Fisheries Nautical and
Engineering Training (CIFNET), and the Integrated Fisheries Project (IFP). The National Fisheries Development Board (NFDB) was established in 2006 at Hyderabad with an aim to enhance fish production and productivity in the country. The Marine Products Export Development Authority under the Ministry of Commerce has contributed immensely in promoting the export of the processed product. This statutory body has its own research wing and seagoing facilities and also funds for research programmes in aquaculture and postharvest technologies. The National Bank for Agricultural and Rural Development (NABARD) with its active financial support for infrastructure development has also its important share of contribution for the development of the sector. This funding agency has come up with many schemes and support for financing the fisheries and aquaculture activities in the country.

Sectorial growth of aquaculture largely depends on availability of quality seed, feed, fertilizers, therapeutics etc. While technology generation was the domain of research organisations both in government and private sectors, the implementation of the technologies had been possible with the involvement of the allied industries producing these inputs. The last two decades have witnessed participation of many corporate bodies in the aquaculture development process both in research and production. Many corporate sectors have come up to establish feed mill and produce other aquaculture inputs. Supply of balanced feed has triggered aquaculture industry for higher fish production. Similarly, timely availability of many drugs and therapeutics had significantly reduced the risk of crop loss and thereby, promoted the aquaculture activity. The processing industry involved in the sector also has their indirect impact in the development process.
<table>
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Recommendations

Capacity building

Efforts to improve the skill level and technical efficiency of the humane resource engaged in the aquaculture and fishery sector has made it possible to reach 7.77 MMT production levels of fish from the culture sector in India placing it the 2nd largest producer in the globe. However, the country needs to remain more competitive to cater the ever increasing domestic fish demand and also to tap the export market. The Fisheries Department of all the States are engaged in a continuous process of developing the humane resource component in the sector through training and demonstration and the programmes are facilitated by NFDB. Regular trainings are also being organized by the 694 widely distributed KVK systems, NGOs and other organization. Government of India has lunched the skill development programme under which huge number of stake holders at different levels of the production chain are going to be trained. Presently, information and communication technology (ICT) revolution is already in playing a key role in increasing the awareness among these stake holders through ICT facilitated communication, processing and transmission of information. This is expected to lead the country to a new height in fish production in the coming years.

Policy development

Fish production in the country needs to be increased on a continuous basis to cater the protein demand of the growing population and the responsibility lies mostly on the aquaculture sector. But things are not in favour of this target. The list of problems include diminishing per capita land and water availability, climate change, loss of biodiversity, dispersed nature of resources, poor literacy among fishers, inadequate inputs availability, increasing labour cost, inadequate feed ingredients, high capital requirement, lack of infrastructure and cold chain, non-existence of an export market for freshwater fish and the list goes on. The pressure on the freshwater culture sector can be reduced through parallel development of the brackishwater culture sector and promotion of culture based capture fisheries in the inland waters. Thus, the aquaculture development in the country largely should rely on the coherent approach and effective planning for sustainable and judicious utilization of the available resources.
Livelihood

The flexibility in the scale of operation of fish farming offers scope as an important livelihood option for small, marginal and big farmers. Effective planning of farming suiting to the resource either in the form of seed rearing or grow-out culture can prove to be an ideal livelihood option with adoption of right kind of farming technology.

Conclusion

India is primarily an agrarian society where almost two third of the 1.3 billion population live in more than 6,38,365 villages. Despite an explosive increase in the population, India has been able to become self-sufficient in the food production. This has been achieved with the active participation from the rural sector with a strong technical back up from the R&D activities of the agriculture and allied sectors and effective implementation of several major programmes under the Green, White, Blue, Yellow and Rainbow revolutions. Under the Blue Revolution programme, launched for the second time, several development programmes starting from infrastructure development, technological back up and financial support to skill development at all levels of the production chain have been initiated and expected to keep the aquaculture sector competitive and vibrant. Majority of the pond resources in the country are of small and homestead nature. But the flexibility of scale of operation of the fish farming can provide every beneficiary in the sector his share of profit and livelihood. Of late, slowing down of growth rate in agriculture sector is often failing to retain the existing population in the profession while fancy towards urban life has been other deterrent for the rural youth to engage in the agriculture activity. In this context, aquaculture with its annual growth rate at more than 6% per year can be an ideal option to retain the youth mass in the business. Efforts have been made over the years through implementation of several schemes with due consideration of the above factors to reorient the rural populace to agriculture and allied activities. Such programmes are also being implemented with the able support of the R&D activities to improve the yield, reduce the operational cost, post-harvest value addition, market support and improvement in farm income. Recent lunching of ‘Doubling the farm income’ by Government of India is one of these kinds.

References


Chapter 3

Aquaculture of Commercially Important Finfishes in Bangladesh

Kazi Iqbal Azam
Department of Fisheries, Government of Bangladesh
Dhaka, Bangladesh
kaziiqbalazam@yahoo.com

Aquaculture scenario in Bangladesh

Bangladesh is a densely populated country in South Asia with more than 168 million people, live in 147,570 sq. km (56,977 sq. miles) area. A wide portion of land is covered by large international and cross boundary rivers such as Padma, Jamuna, Teesta, Meghna, Brahmaputra and Surma. Besides, there are thousands of tributaries with a total length of about 24,140 km. These rivers are connected to the Bay of Bengal. The tropical climate of Bangladesh is agriculture friendly, particularly fisheries sector has enormous unexplored resources of open waters with vast opportunity for aquaculture expansion. With having the world’s largest flooded wetland and possessing the third largest aquatic biodiversity in Asia, behind China and India, Bangladesh is considered as one the most suitable region for aquaculture and fisheries in the world. The country has an inland water area of about 45,000 km² and about 710 km long coastal belt. Fisheries play an important role in the economy and the diet of the population. Fish and fish products supply 60% (DoF, 2018) of the country’s animal protein intake and around 3% of total export earnings. From 2000 to 2018 aquaculture production has increased from 712,640 t to 3,496,958 t, a much larger quantity than wild capture production (1,163,606 t) in 2018. However, fisheries production is still below the targets despite the large gains seen in the aquaculture sector.

Fish is the popular complement in the Bangladeshi diet, giving rise to the adage *Maache-Bhate-Bangali* (“Bengali is made of fish and rice”) (Ghose, 2014). The fisheries can broadly be classified into three categories, inland capture fisheries, inland aquaculture and marine fisheries, of which the inland aquaculture sector is contributing more than 55% of the total aquaculture production (DoF, 2018).
The fisheries sector plays an important role in the national economy, contributing 3.61% to the Gross Domestic Product (GDP) of the country and 24.41% to the agricultural GDP (DoF, 2018). Over the last 10 years (2004-2005 to 2016-2017) the fisheries growth was fairly steady and at an average of 5.24% per year (DoF, 2018; Fisheries Master Plan, 2018). Given proper government support, the fisheries sector has ample potential in creating various types of ancillary industries in rural areas that often have a high rate of economic return. These employment opportunities for poor rural citizens would also stem their migration to urban areas. More than 17 million people including about 1.4 million women depend on fisheries sector for their livelihoods through fishing, farming, fish handling and processing (BFTI, 2016). A survey revealed that more than 80% of laborers engaged in the fish processing industries are women (DoF, 2018).

Bangladesh has one of the biggest and most active deltas, fed by three mighty rivers: the Padma, the Meghna and the Jamuna. This contributes to a high potential for fresh water capture, brackish water capture and culture fisheries, in addition to the vast marine resources.

Despite Bangladesh’s long coastline and large freshwater and marine water bodies, fisheries are under developed compared to other industry sectors. Inland fisheries production has escalated over the years, but the productivity per hectare water area has not yet attained its optimum potential. Bangladesh ranked 5th in inland aquaculture production and 3rd in inland capture fisheries production, which accounted for half of the country’s total fish production (56.24%; 2.41 million t and 28.45%; 1.22 million t) (DoF, 2016; FAO 2018).

As indicated in the fig.1, inland open water fisheries are still a major source of the total fish production, but their share has declined from 62.59% in 1983–
84 to only 28.45% in 2017–2018. Conversely, inland closed water fisheries contribution has increased from 15.53% in 1983-84 to 56.24% in 2017–2018. The contribution of marine fisheries over the same period has dropped from 21.30% to 16.28%. The average yield (annual fish harvest per hectare in t) in open inland waters declined throughout 1983–84, but improved sharply afterward. Pen and cage culture are two new approaches in fish culture in Bangladesh and contributed significantly in the total fish production during last decades.

![Figure 2. Sub-sector wise fish production trends in last 15 years](chart.png)

**Commercially important finfishes**

**Freshwater**

1. Rui (*Labeo rohita*)
2. Catla (*Labeo catla*)
3. Mrigal (*Chirrhinus chirhosus*)
4. Kalibaus (*Labeo calbasu*)
5. Gonia (*Labeo gonius*)
6. Bata (*Labeo bata*)
7. Shing (*Heteropneustes fossilis*)
8. Magur (*Clarias batracus*)
9. Pabda (*Ompok pabda*)
10. Gulsha (*Mystus cavasius*)
11. Chitol (*Chitala chitala*)
12. Shoal (*Channa striatus*)
13. Cuchia (*Monopterus cuchia*)
14. Koi (*Anabas testudineus*)
15. Gang magur (*Hemibagrus menoda*)
16. Rita (*Rita rita*)
17. Mohashol (*Tor tor*)

**Brakishwater**

1. Vhetki (*Lates calcarifer*)
2. Bhangan bata (*Mugil cephalus*)
3. Parse (*Chelon subviridis*)
4. Nona tengra (*Mystus gulio*)

In marine water no species is identified for aquaculture.

Other than the above listed freshwater and brakishwater species, there are 12 exotic fish species are successfully cultured in Bangladesh.

**Prospects of commercially important finfish aquaculture**

At present, major carps species such as *Labeo catla*, *Labeo rohita*, *Cirrhinus cirrhosus* and *Labeo calbasu* along with exotic carps, such as silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*) are produced through aquaculture. The IUCN (2000) reported that many of the small indigenous fish are now endangered or critically endangered. There are about 40–50 small indigenous fish species which grow to a maximum length of 25 cm (Felts et al., 1996) found in open waters. Among them Gulsha (*Mystus gulio*), Pabda (*Ompok pabda*), Puti (*Puntius sarana*) and Mola (*Amblypharyngodon mola*) are being cultured in inland water bodies (ponds and lakes). The carps contribute 33.57% of total annual fish production followed by Pangas (*Pangasiastodon hypophtalmus*) (11.404%), and tilapia (*Oreochromis hypophthalmus*) (8.44%) (FRSS, 2016). However, the inland water resources of Bangladesh offer major potential for the development of freshwater aquaculture (Hossain, 2014).

Freshwater aquaculture is mainly comprised of pond farming of carps (indigenous and exotic), Mekong pangasid catfish, tilapia, Mekong climbing perch and a number of other domesticated fish. Coastal aquaculture constitutes mainly of shrimp and prawn farming in ghers (coastal pond or enclosures). Marine aquaculture is not practiced in the country at present.
In Bangladesh, aquaculture production systems are mainly classified into extensive, improved extensive, semi-intensive and intensive systems (Hossain, 2014). The present aquaculture productions (t/ha) are 3.60, 1.50, 0.95 and 0.71 for the pond, seasonal water-bodies, Baor (oxbow lake) and shrimp gher, respectively. Inland pond culture is the mainstay of Bangladesh aquaculture accounting more than 80% of the total aquaculture production and is dominated by carps (indigenous and exotic), Mekong Pangas (Pangasianodon hypophthalmus) and tilapia (Oreochromis niloticus). The brackish water giant tiger prawn (Penaeus monodon) and giant river prawn (Macrobrachium rosenbergii) are the main cultured species in coastal areas of Bangladesh.

The coastal and marine environment of Bangladesh is blessed with a warm tropical climate and high rainfall, enriched with nutrients from the land, creating one of the world’s richest ecosystems with high productivity. Exploration and management of living and non-living resources of the Bay of Bengal have potential to substantially contribute to the economy of Bangladesh. Particularly after the recent decision of the International Tribunal for Law of the Sea (ITLOS) regarding the Bangladesh-Myanmar maritime boundary, 2012 and the decision of the Arbitral Tribunal of the UNCLOS on India-Bangladesh maritime boundary, 2014 established sovereign rights on more than 118,813 km² area of territorial sea and 200 nautical miles (NM) of Exclusive Economic Zone (EEZ) and all kinds of living and non-living resources under the continental shelf up to 354 nautical miles from the Chittagong coast (MoFA, 2014). There are 260 fresh water indigenous fish species, 12 exotic fish species and 475 finfish species in Bangladesh.

In 1990s and 2000s the country put efforts to increase the fish production for ensuring the nutritional security of the increasing population. In addition, at present emphasis are giving on food standards, safety and quality of the produced fishes and preserving environmental sustainability in compliance to national requirement and increase access to global market. Till 2010 emphasis was laid on increasing fish production, at present emphasis are giving on addressing the quality, traceability, health hazards etc.
Present hatchery production, seed rearing and aquaculture practices and production of commercially important finfishes

Hatchery production of commercially important finfishes is described in Table 1. About 10 important finfishes production are still in under research. Seed rearing are generally accomplished by following GAP issues and almost all nursery uses hand-made as well as commercial fish feed. Intensification for the vertical expansion of closed water aquaculture contributed significantly during last two decades. The country has attempted to utilize its vast seasonal water bodies like flood plains, fallow rice fields, beels, canals and natural depressions adopting extensive aquaculture involving community-based cage aquaculture though it is in initial stage Bangladesh Fisheries Research Institute (BFRI) and private hatchery owner are trying to develop breeding, nursing and feeding technique to breed, nurse and rearing of the SIS species in Bangladesh.

Table 1. Hatchery production of commercially important finfishes in Bangladesh

<table>
<thead>
<tr>
<th>Fish species</th>
<th>Hatchery Production (kg/yr)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indian Major Carps Rui (<em>Labeo rohita</em>)</td>
<td>260,776</td>
<td>FRSS 2017</td>
</tr>
<tr>
<td>Catla (<em>Labeo catla</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mrigal (<em>Chirrhinus chirhosus</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bata (<em>Labeo bata</em>)</td>
<td>29,713</td>
<td>FRSS 2017</td>
</tr>
<tr>
<td>Shing (<em>Heteropneustes fossilis</em>)</td>
<td>16,252</td>
<td>FRSS 2017</td>
</tr>
<tr>
<td>Magur (<em>Clarias batractus</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pabda (<em>Ompok pabda</em>)</td>
<td>32,487</td>
<td>FRSS 2017</td>
</tr>
<tr>
<td>Gulsha (<em>Mystus cavasius</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chitol (<em>Chitala chitala</em>) and others</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoal (<em>Channa striatus</em>)</td>
<td>Under research</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. Cage aquaculture in rivers of Bangladesh
<table>
<thead>
<tr>
<th>Fish species</th>
<th>Hatchery Production (kg/yr)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Freshwater</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cuchia (<em>Monopterus cuchia</em>)</td>
<td>Under research</td>
<td></td>
</tr>
<tr>
<td>Koi (<em>Anabas testudineus</em>)</td>
<td>Under research</td>
<td></td>
</tr>
<tr>
<td>Gang magur (<em>Hemibagrus menoda</em>)</td>
<td>Under research</td>
<td></td>
</tr>
<tr>
<td>Rita (<em>Rita rita</em>)</td>
<td>Under research</td>
<td></td>
</tr>
<tr>
<td>Mohashol (<em>Tor tor</em>)</td>
<td>Under research</td>
<td></td>
</tr>
<tr>
<td><strong>Brakish water</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vhetki (<em>Lates calcarifer</em>)</td>
<td>Under research</td>
<td></td>
</tr>
<tr>
<td>Bhangan Bata (<em>Mugil cephalus</em>)</td>
<td>Under research</td>
<td></td>
</tr>
<tr>
<td>Parse (<em>Chelon subviridis</em>)</td>
<td>Under research</td>
<td></td>
</tr>
<tr>
<td>Nona tengra (<em>Mystus gulio</em>)</td>
<td>Under research</td>
<td></td>
</tr>
</tbody>
</table>

Last decade, farmers are practicing low stocking density with bigger fingerling technique to increase fish production but that was not economically viable. Nowadays farmers are stocking a smaller number of fingerling (wt. 250g-500g) in the grow-out pond and get more profit from this practice.

The introduction of good aquaculture practices (GAP) was designed from fundamental to advanced aquaculture related activities on improving overall farm performance which was also expected to result in additional environmental benefits especially farm profitability. Demonstrating profitability of any innovative technique will encourage the adoption rate by the farmers. The positive outcomes of GAPs adoption include increased fish production, lowered feed cost and reduced impact of aquaculture on surrounding environment (Ansah et al., 2013). Commercial farms in Bangladesh also deal with the adoption and impacts of GAPs on fishers’ incomes, production and profit. Results suggested that about 1.5% higher profit was observed in all such cases. Some of the finfishes have bright future in aquaculture in Bangladesh.

**Shoal (*Channa striatus*)**

*Channa striatus*, known as ‘Shoal’ or ‘Snakehead’ is a commercially important finfish species in Bangladesh which contributes 2.09% of the total fish production in the country (FRSS, 2018). The flesh of Shoal fish is firm, white, and almost boneless and has consumer preferred flavor. Its flesh is claimed to be rejuvenating and widely consumed for its nutritional value as well as for its beneficial effect in wound healing (Mat et al., 1994). It is also well known for its therapeutic properties, particularly for pain reduction in osteoarthritis (Michelle et al., 2004). Shoal is available in freshwater ponds,
prefers stagnant muddy water and grassy tanks, breeds almost throughout the year in the flood plains with low water in the monsoon.

Figure 5. Shoal (*Channa striatus*)

The published literature is scarce and the production of this fish from the natural water bodies is declining gradually. Artificial breeding has been attempted for this species with limited success (Duong et al., 2004, Haniffa et al., 2000). The culture practice of this species is not well-defined as done for the Indian major carps (IMCs). Seeds of this species are often collected from the natural habitat which is unreliable and may seriously deplete the natural stock in near future. The higher market price and consumer demand make the species a good candidate for aquaculture. The fish is being cultured at some parts of the country in a very sporadic way. Tania et al. (2016) reported that 40 fish/decimal and were fed with hatchery originated live fish fry of Bata (*Labeo bata*), Mrigal (*Cirrhinus cirrhosus*) and Silver carp (*Hypophthalmichthys molitrix*) at the rate of 1-3% of the total body weight and a supplementary feed combination of rice polish, mustered oil cake and fish meat at the rate of 3-5% of the total body weight was economically viable. More studies are required to develop artificial feeds and induced breeding techniques that are two big challenges for the aquaculture of this species.

**Rita (Rita Rita)**
*Rita rita* (Hamilton, 1822) is a highly valued bagrid catfish in the Indian subcontinent belongs to the order Siluriformes and popularly known as ‘Rita’. It is one of the giants of its genus, growing to a length of 150 cm (Talwar and Jhingran, 1991). Generally, it inhabits muddy to clear water and grows in large rivers (Shaji, 1995) and shallow water of estuaries, *haor, baor, beels* and brackish water ecosystems (Talwar and Jhingran, 1991; Yashpal et al., 2006; Siddiqui et al., 2007). It is a potamodromus, bottom and column feeder, usually feeds on insects, molluscs, shrimps, fishes, roots of aquatic plants and also putrid carcass of animals (Siddiqui et al., 2007). The abundance of this fish was reported as very rich in Afghanistan, Pakistan, India, Nepal, Bangladesh and Mayanmar in the past (Tripathi, 1996). Though the fish is harvested from the wild fairly in a large quantities, but its catch is progressively declining due to the collective effect of different factors, such as massive siltation in natural habitats, loss of breeding and nursery grounds, overexploitation, alteration of habitats and ecological modifications like blocking of migratory channels by construction of food control dams, roads and highways, townships and other developmental infrastructures, irrigation schemes, destructive fishing pressure (IUCN, 2015), aquatic pollution through pesticides and chemicals (World Bank, 2005) as well as short term leasing of *haor, baor and beels*. Consequently, the species has been documented as “Endangered” in Bangladesh (IUCN, 2015), “Near Threatened” in India (Gupta, 2015) and as of "Least Concern" globally (IUCN, 2015). As natural population of the species is declining fast, planners, policy makers, aquaculturists and fishery biologists are thinking of its domestication and cultivation through farming to sustain and augment its production.

The fish is very popular for its good taste. Its flesh is rich in protein (17.22-19.55%), low in fat (1.01-2.70%) and has good amount of minerals (0.89-1.07%) compared to other teleosts as well as catfishes (Mitra et al., 2017). Considering its high market demand, the riverine catfish *R. rita* could be a prospective candidate for aquaculture in Bangladesh and there is an urgent need to establish domestication, cultivation and artificial propagation of the species, to augment the natural population, meet the high demand and help in conservation of the species. Some attempts have been taken to develop culture techniques for the fish, such as induced breeding (Mollah et al., 2008), induced breeding and larval rearing (Taslima and Mollah, 2012) and effect of different feeds on growth and survival (Amin et al., 2010; Muhammad et al., 2018). But the influence of stocking density on the production of this important fish is yet to be elucidated. Stocking density is known to have a profound influence on fish growth, survival, behavior and production in any aquaculture system, especially in monoculture.
Replication of this breeding technique and domestication to artificial feeding would be a measure for monoculture both in ponds and cages.

**Kuchia (Mud eel)**

There is no culture practice of mud eel in Bangladesh. But the “Culture of Cuchia (mud eel) and Crab in the selected area of Bangladesh and research project” was introduced seed production and two culture methods of mud eel. The fry was collected from nature and cultured. There is a good success in control natural breeding for seed production in five Fish Seed Multiplication Farm (Sadar and Durgapur, Netrokona; Fulpur, Mymensingh, Nimgachi, Sirajgonj and Parbotipur, Dinajpur) of Bangladesh. Supplementary feed was not practiced as a ration of its life in farmer’s level. The source of fry collection is wild environment. Commercial fry producing technique and domestication to artificial feed would be future research area.

**Mahseer (Tor tor)**

Among the fishes of family Cyprinidae, red fin mahseer *T. tor* is one of the most attractive fish of Bangladesh. It has high demand as table fish and lure for anglers as a game fish and is potential contender for aquaculture (Haque et al. 1995; Ingram et al. 2005; Ogale, 2002). Due to attractive color, it has high potential as ornamental fish in the aquarium fish industry (Ng, 2004). In the past, *T. tor* was reported to be available in the hilly streams of Sylhet, Mymensingh, Netrokona, Dinajpur, and Kaptai reservoir of Chittagong Hill tracts in Bangladesh (Rahman, 1989). But in last couple of years, it is very rarely found only in the River Someshwari of Netrakona District (DoF, 2016). Because of various natural causes and manmade activities, the water flow of Someshwari has been reducing abruptly resulting loss of habitat of mahseer.
Besides, the river is being used for livelihood of poor and ultra-poor people which is also responsible for degrading the habitat. People especially women, even children go to the river to collect coal particle and sand for their livelihood. Illegal gears are also used in the Someshwari for fishing. Moreover, unscientific coal mining in the upstream of the Someshwari at Meghalaya, India has provoked the problem incorporation with acid mine drainage (Mallik et al. 2015). Consequently, *T. tor* has been ranked as critically endangered in Bangladesh (IUCN, 2015).

*T. tor* is the symbol of aristocracy but did not get due attention from any corner of stockholders for its conservation. As *in-situ* conservation is practically impossible in the existing habitat, *ex-situ* conservation through domestication in captivity is a must to protect *T. tor* from extinction. Domestication of mahseer in captivity will also help to determine its culture potential. Over the last few decades, though some research on growth parameter and nutritional requirement of other species of *Tor* (Bista et al. 2002; Chatta et al. 2015a, 2015b and 2015c) have been conducted, very little information (Akram and Swapna, 2014; Lone and Lone, 2014) on *T. tor* have come to the light. Therefore, the present study was aimed to domesticate *T. tor* in captivity and to find out the appropriate supplementary feed as well as protein requirement for this species. As it is critically endangered, the way of artificial propagation is a burning issue concerning robust growth of mohashol and multilateral initiative with India, Nepal and other South Asian countries.

**Gang magur (Hemibagras menoda)**

The fish is very popular for its good taste and high nutritive value. Considering its high market demand, the Gang magur could be a prospective candidate for aquaculture in Bangladesh and there is an urgent need to establish domestication, cultivation and artificial propagation. Some attempts have been taken to explore the reproductive biology and domestication in captive condition (Jega et al., 2018). They also got preliminary success in artificial breeding. Though this fish was not included in IUCN Red List, Bangladesh but practically it is very rear. Considering the aquaculture potential, immediate development of artificial breeding, nursing and culture technique should be developed.

![Figure 9. Menoda catfish](image-url)
**Koi (Anabas testudineus)**

The climbing perch (*Anabas testudineus*) is very hardy fish and can survive in adverse environmental conditions such as low oxygen due to its air breathing ability, wide range of temperature and poor water quality. High market demand and good taste makes the fish very lucrative. This perch is efficient converters of organic and agricultural wastes into high quality protein. These are also resistant to disease and can be cultured at relatively high stocking densities. Some attempts have been taken to explore the artificial breeding technique but no success (personal communication).

![Figure 10. Koi (Anabas testudineus)](image)

**Bhetki (Lates calcarifer)**

Bhetki, *Lates calcarifer* (Bloch, 1790) is one of the most commercially important species which is relatively new in Bangladesh. Although the farming practice of this species is relatively new, it is gaining prime preference among the consumers due to its nutritive value, taste and high flesh content compared to other commercially important species available in the entire coastal area.

![Figure 11. Lates calcarifer](image)

Recently, Bhetki has established in the southern part of Bangladesh, more specifically, in the southwestern coastal area in semi-intensive and extensive farming systems. Techniques for fry production of Bhetki were developed in Thailand in the 1970s and further developed by several research institutes in the Philippines, Singapore, Hong Kong, and Australia. To date, there are no well-established Vetki hatcheries in Bangladesh. A few nurseries rear wild sourced fertilized eggs and fry to fingerling. These nurseries are mostly located in Kaliganj *upazila* (sub-district) under Satkhira district. Coastal water estuaries (Ganges delta) are considered as major spawning, nursery and feeding grounds of this fish. Vetki fry and fingerlings are collected from the coastal Sundarban area, especially during the post monsoon period when shrimp post larva (PL) are also abundant. Collection methods are predominantly with indigenous equipment including set bag net and small mosquito net. These collected fry
and fingerlings are sold in selected markets. Farm owners use these wild caught and nursery grown fry and fingerlings in their coastal brackish water farms.

In semi-intensive farming systems in Bangladesh, farms are usually divided into two sections; the large one is used for shrimp culture, in which native tilapia are used as live food for Vetki. These fish are highly fecund, constantly producing larvae in these ponds. The small section of the farm is used to stock Vetki until the end of shrimp farming. Between July and September, almost all shrimp are harvested and sold, with the whole farm being dedicated to Vetki farming until the next season of shrimp culture. Vetki are restocked during December to February. The omnivorous juvenile stage and the carnivorous post-juvenile stage of Vetki greatly influence the feed input. There are no species specific artificial feeds available in the market for Vetki in Bangladesh and the farmers depend on locally made food and live food (tilapia) that is grown concurrently with the shrimp farm. In practice, the limiting factors in profitability in Vetki farming is mainly due to the lack of quality, commercial feed and lack of hatchery produced fingerlings. Other factors impacting profitability and viability include costly live food inputs.

- Establishment of adequate numbers of hatcheries to meet the demand of seed
- Introducing selective breeding to improve qualitative and quantitative attributes of the fish
- Establishment of commercial feed industry to produce species specific feed
- Ensure high-quality marketing facilities to expand market demand at both national and international level.

Parse (Chelon subviridis)

Parse, Chelon subviridis (Val. 1836) earlier known as Liza subviridis belongs to the Mugillidae family is a catadromous fish and widely distributed in the coastal waters of tropical and sub-tropical regions. It is a euryhaline and eurythermal fish. This fish is locally known as parse/bata and commonly available in shallow coastal waters, estuaries and mangrove swamps of Bangladesh. The

Figure 12. Green back mullet (Chelon subviridis)
high quality of flesh, high economic value and wide temperature and salinity tolerance capacity make this species popular for aquaculture in the intertidal ponds. There are about 1.5 million ha brackish water ghers in the south-west region of Bangladesh. At present, the farmers depend upon wild seed for stocking to their ghers. Due to indiscriminate harvest from natural sources and some environmental reasons the abundance of this fish is decreasing day by day. There is no alternate supply of seed from artificial sources to conserve the natural biodiversity and increase production of this fish. Chelon subviridis has high demand in the national and international market. It is now imperative to develop a suitable culture technology of this species to increase productivity of the ghers. Long back, a few attempts were made by Bangladesh Fisheries Research Institute and studies were conducted on the production potential of this fish with shrimp, using mullet seed from wild source. Recently Saha and Kabir (2014) reported the preliminary success of breeding of this fish in captivity. For commercial culture, specific artificial balanced commercial feed should be developed. Primary success of artificial breeding tends to regular success should be considered simultaneously.

**Nona tengra (Mystus gulio)**

*Mystus gulio*, locally known as ‘Nona tengra’, is a euryhaline estuarine small catfish commonly occurring in the coastal waters of Bangladesh. This species is supporting the coastal fisheries of Bangladesh to a great extent, both in point of commercial and local point of view. Though, the fish has naturally being caught every year in fairly a large quantity, its catch is gradually declining due to over-exploitation, destructive fishing practice, loss of habitat, and different ecological modifications. The fish has high market demand and delicious in taste and emerged as an aquaculture species in the coastal Bangladesh. For conservation and increasing supply of this fish, Bangladesh Fisheries Research Institute has developed breeding technology of this fish in 2007. This has paved the way of establishing and expansion of aquaculture of the species. Expansion of aquaculture of any fish is greatly dependent on its ensured supply of seed for grow-out culture. Nursing of yolk absorbed spawn in the nursery pond seems to be very sensitive, as they pass through a critical period of switching over from natural food to artificial feed and also need to adjust with new environment from indoor hatchery to outdoor

![Image of Nona tengra](image-url)
earthen pond. Considering the euryhaline nature, this fish has potential for culture in both brackish water as well freshwater ponds. This fish may be very much suitable for culture with shrimp (*Penaeus monodon*) in brackish water ghers. This may help to save the shrimp farmers from losing their investment in case of invasion of viral disease in shrimp which is very common in the coastal ghers. Fish were fed with commercial pellet feed (30% crude protein) at 4-6% of estimated fish biomass with the stocking density of 16/m² density showed better performance.

**Bhangan Bata (Mugil cephalus)**

Introduction Striped mullet (*Mugil cephalus*), locally called as Khorul bata/Bhangan bata is a commercially important, high priced marine finfish in Bangladesh coast. The species is euryhaline and eurythermal that contributes to sizable fisheries of estuarine and coastal regions not only in Bangladesh but also throughout the world including China (Chang et al., 2000), India (Barman et al., 2005), Sri Lanka (De Silva and Silva, 1979), Taiwan (Chang and Tzeng, 2000) and Tunisia (Kheriji et al., 2003) etc. Full-scale commercial production of the species is not common in the country, although the species is considered as highly demanded species because of its good taste. In the Indian sub-continent, induced breeding of mullets by pituitary extract injection was first initiated in India during 1961 and success was achieved in breeding of *M. cephalus* by hypophysation (CIFRI, 1961). Another successful attempt of induced spawning of *M. cephalus* reared in captivity was by Yashouv (1969) using carp pituitary gland and luteinizing hormone, and HCG by Kuo et al. (1973). Kuo et al. (1974) also established spawning procedure for *M. cephalus*. Although, the mullet fry and juveniles are abundant in the wild, aquaculture cannot thrive depending on the wild fry supply. Mass production of mullet seed/fry will expand its widespread aquaculture in the coast. So we need to develop artificial breeding technology of mullet in captivity. Study on reproductive biology of *M. cephalus* in Bangladesh attempted (Das et al., 2008), although induced breeding techniques of this species not yet developed. Thus, to ensure adequate supply of seed for the culture, knowledge about its artificial breeding is prerequisite.
and hence the present experiment was conducted in a fish hatchery at Cox’s Bazar, Bangladesh. Ehsanul et al., (2015) found that artificial breeding trial of *Mugil cephalus* using hormones CPG and HCG was successful. They collected from wild and reared in saline-water ponds to breed in captivity through hormone induction. The salinity of rearing ponds was maintained between 20 – 25ppt and in hatchery 24 – 25ppt with 22 – 25°C temperature. The GSI value of fecund fishes ranged from 7.92 to 12.38, egg diameter of matured fish between 550 to 600µm and that of fertilized egg from 650 to 700µm. Fecundity was calculated as 735 to 900 egg/g. The fish started spawning between 44 – 48 h and cell division was observed after the first hour of spawning but severe mortality occurred after 6 h. Although initiatives has been undertaken by the Govt. but the present consultation meeting might have huge contribution to achieve the above mentioned activities.

**Issues and Challenges**

*Environmental issues*

- The fisheries sector in Bangladesh is confronted with a range of environmental impacts. In floodplain 54 fish species are in danger of extinction and the pressure of fishing is so high in floodplains that less than 2% of produced fish survive till the end of each year.
- Excessive and unregulated nutrient loadings cause acidic soil in aquaculture farms.
- Excessive use of underground water in aquaculture in North Bengal may shift underground water level.
- Disease transmission by contamination either by commercial fishers (people engaged in fish catching- as a livelihood option) or by aquatic birds.
- The escaped fish from commercial cages, installed in open water bodies like- rivers, creeks and haor, might harm the native aquatic biodiversity.
- Uncontrolled and unregulated use of AMPs (Aquatic Medicinal Products) in commercial finfish and shrimp farms all over the country.
- Salinization of agricultural land as a result of coastal finfish and shrimp farming.

*Social issues*

- Conflicts arise when introducing commercial cage aquaculture in open water bodies because it may create water sharing activity by other inhabitants of that locality.
• Construction of finfish cage aquaculture in the area of haor, may create disputes between the leasee of the khas water body or jalmahal and the entrepreneurs of the cage aquaculture groups.

• Multi-ownership of aquatic resources (Ponds, lakes, Khas land allocated from government to rehabilitate the landless poor in Bangladesh.

• Disputes arise when conversion of fertile agricultural land into finfish farms because of breaking the roads or communication path due to excessive fetching of transports to complete marketing the aqua-produce.

Planning and management issues

• Registration of finfish farms: Government has taken initiative to register the aquafarms to ensure the traceability of the aqua-produce because FVO mission of EU given guidelines to get healthy aqua-produce from Bangladesh.

• Aquaculture diversification: Among all commercially culture finfishes in Bangladesh only few species are successful in aquaculture. Standardization of technologies for seed production and rearing technologies for commercial finfish production are the main tasks. Domestication of new native and exotic finfishes for diversified aquaculture systems i.e. cage culture, pen culture and RAS would be urgent need to upsurge the aquaculture production.

• Transfer of Technology: Technology transfer in the fastest way for expansion of new innovative finfish aquaculture technique to the feasible resource areas and viable implementers.

• Introduction of GIAS (Genetically Improved Aquatic Species): GIAS is under the initiatives of GMOs (Genetically Modifies Organisms) have been brought into commercial finfish aquaculture. It satisfies the demand of all stakeholders in aquaculture ventures. Like GIFT tilapia, new species should be brought into this system to boost up finfish production.

• Aquaculture zoning: To overcome the local conflicts newly raised due to new establishment finfish farms in Mymensingh and other division in Bangladesh, aquaculture zoning is a must. Perfect use of our vast open water and marine resources for cage culture aquaculture zoning is very essential. For establishing brackish water aquaculture, aquaculture zoning is essential because brackish water aquaculture might create problems in terms of salinization and pollution of neighboring land areas also.
• **Seed certification and accreditation program for importing exotic fin fishes**: Fisheries quarantine Act 2018 has developed to protect inland fisheries resources from disease and health managements issues in Bangladesh.

• **Incentives to ensure low cost commercial fish feed**: Government has taken initiative to deduct tax on imported raw materials for ensuring low cost feed for aquaculture development.

• **Infrastructure development**: Infrastructure development to reduce the loss of post-harvest aqua-produce and increase the export of aqua-produce.

• **Farm mechanization**: Farm mechanization through mechanical device like aerator, automation of pond aquaculture systems by advanced farmers are playing key role to ensure better management services and ensure economic profitability.

• **Extension services**: As a part of ‘Digital Bangladesh’, Department of Fisheries has initiated mobile apps (Fish Advice System) and web services (Online registration for both hatchery registration and feed licensing) to ensure fastest services for aquaculture practices and management.

**Issues related to export of aquaculture products**

Fish and fishery products are the main food commodities in Bangladesh. Products should be free from adulteration and chemical contaminants. The unregulated use of antibiotics in finfish and shrimp cultivation emerged as the threat to the export of these products. This aquaculture sector earned major foreign currency in the last year. HACCP-based fish processing plants helps to continue the current foreign earnings. Government has initiated several regulations to overcome the export problems viz., Fish and Fish Product Inspection and Quality Control Act 1985, 2008 and proposed 2013, which stated as,

- Any fish and fish products which quality and safety parameters are not fulfilling the standard criteria settled in law and may affect public health should not be produced, transport, storage, handling or marketing for human consumption or any intentional use that have risk of health hazards.

- Input suppliers, producers, handlers and marketing stakeholders must follow the Codes of Conduct and implement GAP, GHP and GMP through the fish value chain to ensure safe food production and consumption.
• Violation of any instructed CoC or legal procedure may impose punishment of any stakeholders in the Fish/Shrimp value chain

Other challenges

• Low cost quality feeds and seeds: These are the two big challenges in Bangladesh that hinders the finfish aquaculture.

• Induced breeding technique: Development of artificial induced breeding technique of commercially viable finfish species in Bangladesh is a big challenge.

• Domestication to artificial feed: Habituating to artificial finfish species to take commercial feed for their nursery and grow-out period of life.

• Disease control in aquaculture: Farmers are facing losses in finfish aquaculture due to disease and cause heavy mortality.

• Natural disasters: Each and every year we have to face flood, cyclone and drought. Our fisheries are always fighting with the nature and try to adjust with the situation.

• Climate change: It is an emerging issue for Bangladesh like any other countries. Fish production and breeding season duration is decreasing gradually in inland open waters. We are trying to adjust with the situation by adopting different technologies in closed water aquaculture systems like,
  - Stocking of fast growing fish,
  - Fishes which have market value even they are small in size,
  - Lowering stocking density and larger size fingerlings stocking,
  - Supplying safe and quality supplementary feed (Floating feed) though private fish feed manufacturers try to produce low quality feed.

• Water pollution: Water pollution is another growing threat for the future of fisheries and aquaculture sectors in Bangladesh. Industrial (especially textile and tannery) effluent, fertilizer and pesticide run-off, poor sewerage infrastructure and improper disposal of household waste are the major causes of water pollution in Bangladesh. Rivers and canals near the urban areas are threatened due to sedimentation and siltation, compounded by industrial expansion. At present most of these water bodies are too polluted to support biological systems. Poor urban and industrial management and lack of enforcement of environmental laws are contributing to this pollution spree. The Buriganga river that flows
through the capital city is the most polluted river in the country, many parts of which have already turned coal black.

- **Industrialization:** Here the main problem is the pollutants from different industries which are directly discharged to the river and different open or semi closed water bodies. Waters are becoming polluted and even toxic which directly plays negative role to fish production.

- **Illegal Fishing:** There are some illegal nets in Bangladesh such as Current net, Behundi net (Set bag net) etc. The mono-filamentous synthetic net i.e. current net is directly destroying our fish production and the set bag net is destroying the SIS species in flowing water like rivers and coastal areas. The uses of such nets are strictly prohibited by the laws and regulations. Government is giving maximum efforts to control the production, storage or uses of such nets. However, due to weakness of laws, rules, socio political problem still there have some illegal fishing with these nets mostly in open water resources.

- **Siltation of water bodies and re-excavation (Habitat restoration):** Due to regular flood and other natural calamity the open or semi-open water bodies are getting silted. They need re-excavation. The DoF has taken/implementing water body re-excavation policy from the last 15 years through different GoB projects. The re-excavation activities is ongoing through LCS system and after re-excavation, aquaculture has been initiated at these water bodies through different fish farming groups formed by the dwellers nearest to the water bodies.

**Institutional setup and stakeholder’s involvement**

The Department of Fisheries (DoF) playing the key role for the development of fisheries sector in Bangladesh. DoF along with its’ strong institutional set up actually driving the resource assessment, program planning, implementation, evaluation and expansion of the overall fisheries sector in Bangladesh. Bangladesh is working in close collaboration with Department for International Development (DFID), FAO-UN, USAID, USFDA, EU, World Bank, OIC, JICA, World Fish Center and other international organization to develop the sector by building research partnerships and increasing investment for resources utilization.

**Goals, targets under 7FYP**

- Increased 45% aquaculture production by 2020
- Introduction of mariculture by 2020 especially finfish culture in ghers, pond, pens, marine water also.
• Diversified coastal aquaculture
• Participation of women in aquaculture production, fisheries CBOs and fish/shrimp processing industries should increase to 25%
• Good Aquaculture Practices (GAP) and Good Management Practices (GMP) at all stages of fish/shrimp supply chain to comply the demands of the international markets.

Recommendations

Capacity building

• Research and demonstration project to develop breeding techniques, culture practice, safety and quality assurance of some selective species Vetki (Sea bass), mullet, parse, Nuna tengra etc.
• Generate investment and employment opportunity for private sector enterprises
• Organize environmentally sound, socially acceptable and cost effective aquaculture production for home and abroad.
• Establish training institutes to boost up capacity building.
• Increase skills of both DoF official and fish farmers to adopt new aquaculture practices.
• Resource identification and utilization of blue Bangladesh.
• Hatchery development for potential freshwater/coastal/marine finfish.
• Collaborative research and management protocol on emerging issues, such as- expansion of fresh water/coastal water/marine aquaculture as well as climate change impacts on fisheries resources.
• Infrastructure development to promote sustainable aquaculture practices (viz., fish landing center, market development etc.)
• Empowerment of DoF Officials for implementation of all prevailing Acts.
• Stock assessment of marine resources.

Policy development

• Policy development for proper technology on minimizing water pollution/ water sharing/ under-ground water level/ communication path erosion/escapee from cage aquaculture in open waters.
• Strict implementation of mentioned Acts discussed in above section.
• Already developed fisheries policy should be amended according to current need and introduce policy like RASFF (Rapid Alert System for Food and Feed) and SOPs (Standard Operating Systems).
• Policy should be developed for aquaculture industry like Insurance Policy.
• Disease surveillance policy should be introduced.

**Livelihood**

• Dissemination of adaptive technologies (especially shrimp, prawn, tilapia and pangus) in ecologically constrained/ coastal areas.
• AIG for the coastal fisher community/other stakeholders to support/improve their livelihood, food security and social safety.
• Popularization cage culture technology for developed artificial breeding technique of fin fishes in fresh/coastal/marine areas.
• Ensure adequate safety measures and early warning system for fishers
• Increase utilization of fisheries resources, development of diversified fisheries products for promotion of national and international market.
• Improvement of supply chain/marketing system
• Introduction of,
  - community based fish culture especially cage culture
  - stocking of well known genetic pedigree fingerling in open water natural areas
  - establishment of sanctuaries
  - *beel* nurseries
  - creek development for hill area
  - smart ID card for real fishers for ensuring subsidy to conserve natural stocks
  - pen culture
  - spillway construction etc.

**Information**

• Capacity building of extension workers and fish farmers to ensure food safety and rational use of aqua-drugs
• Motivate, aware poor fishers and other stakeholders to involve in aquaculture value chain from harvest/catch to market/industry
• Preparation of extension material on BMP/GAP and policy issues and distribute evenly
• More disease diagnosis laboratories should be developed
• Harmonization and simplification of existing policies in order to ensure better coordination with finfish farmers

Conclusion

As a very fast growing sector aquaculture has vast scope of contributing to the national economy. The country has huge water resources, good soil fertility, cheap labor and lots of culture-worthy fish species. Besides, as a middle income country, Bangladesh has good possibility of investing more resources in this sector. Proper planning and implementation strategies, latest technology, logistic support and modern technological supports from the neighboring countries can boost the finfish aquaculture development in Bangladesh. Production, import and marketing of fish and shrimp feed, feed ingredients, minerals and vitamin premix, and other inputs, in which private sector is the key player, needs to be constantly monitored by the government. Like the self-sufficiency in crop sector, country achieved self-sufficiency in fish. Development of Fisheries Sector of Bangladesh depends on a bottom-up process following on our Vision-2021, 7th Five Year Plan, SDG goals and targets and Annual Development Plan ADP. Considering the agro-ecological context of the country, there is a wide scope of flourishing the fisheries resource potentials both at vertical and horizontal dimensions. Realizing the sector potentials, government/DoF along with development partners and NGOs has implementing different initiatives to maximize fish production in a sustainable manner specifically in capacity building of officers and other stakeholders, research extension linkage program like this very consultation meeting.

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Chapter 4

Aquaculture of Commercially Important Finfishes in Sri Lanka

J. M. Asoka
National Aquaculture Development Authority of Sri Lanka
asokajm@yahoo.com

Aquaculture scenario

Inland fisheries and aquaculture development was started in Sri Lanka as a major national program during 1970s. By the end of 1980s about 20% of the country’s total fish production was contribution by this sector. The capture fishery in perennial reservoirs and the culture based fisheries in seasonal tanks were achieved in major scales in this period due to Government’s initiatives. The gradual increase of inland fish production from 8,000 to 39,900t was achieved during 1990. However, in freshwater aquaculture sector, especially the programs to encourage pond fish culture were failed to produce anticipated results. The main reason of freshwater aquaculture failure was due to round the year easy availability of marine originated fishes for consumption, all over the country.

With the cessation of government patronage for inland fisheries and aquaculture in 1990, all the programs of the Inland Fisheries Division of the Ministry of Fisheries came to a grinding halt, resulting the inland fish production dropped to 12,000 t in 1994. The aquaculture activities were accelerated again in 1995 with Government initiatives. The National Aquaculture Development Authority (NAQDA) was established (Act No.53) to continue the programs implemented by the former Inland Fisheries Division of the Ministry of Fisheries and Aquatic Resources during 1998.

The fish production from inland, aquaculture and prawn sector grew significantly to 88,010t from 8180t during 2018 compared to the year 2017, which valued approximately 24.86 billion LKR. The production comparison from aquaculture and inland Fisheries in Sri Lanka over the years is shown in Table 1. The contribution of different species to the freshwater fisheries and aquaculture production during 2018 is also shown in Table 2.
Table 1. Comparison of aquaculture and inland fisheries production in Sri Lanka over the years

<table>
<thead>
<tr>
<th>Year</th>
<th>Inland fisheries &amp; aquaculture (t)</th>
<th>Coastal aquaculture prawn production (t)</th>
<th>Total fish Production (t)</th>
<th>% increase over previous year</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>65,640</td>
<td>3,310</td>
<td>68,950</td>
<td>16</td>
</tr>
<tr>
<td>2013</td>
<td>62,480</td>
<td>4,430</td>
<td>66,910</td>
<td>-3</td>
</tr>
<tr>
<td>2014</td>
<td>70,600</td>
<td>5,150</td>
<td>75,750</td>
<td>13</td>
</tr>
<tr>
<td>2015</td>
<td>60,210</td>
<td>7,090</td>
<td>67,300</td>
<td>-11.2</td>
</tr>
<tr>
<td>2016</td>
<td>67,900</td>
<td>6,030</td>
<td>73,930</td>
<td>10</td>
</tr>
<tr>
<td>2017</td>
<td>76,953</td>
<td>5,587</td>
<td>82,540</td>
<td>12</td>
</tr>
<tr>
<td>2018</td>
<td>73,910</td>
<td>14,100</td>
<td>88,010</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 2. Species contribution to freshwater fisheries and aquaculture production in 2018

<table>
<thead>
<tr>
<th>Species</th>
<th>Production (t)</th>
<th>Contribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilapia</td>
<td>51,806</td>
<td>59</td>
</tr>
<tr>
<td>Rohu</td>
<td>2,933</td>
<td>3</td>
</tr>
<tr>
<td>Catla</td>
<td>6,180</td>
<td>7</td>
</tr>
<tr>
<td>Common carp</td>
<td>1,255</td>
<td>1</td>
</tr>
<tr>
<td>Big head carp</td>
<td>8</td>
<td>0.01</td>
</tr>
<tr>
<td>Silver carp</td>
<td>22</td>
<td>0.02</td>
</tr>
<tr>
<td>Mrigal</td>
<td>2,323</td>
<td>3</td>
</tr>
<tr>
<td>Grass carp</td>
<td>19</td>
<td>0.02</td>
</tr>
<tr>
<td>Hiri Kanaya</td>
<td>298</td>
<td>0.34</td>
</tr>
<tr>
<td>Lula</td>
<td>1,644</td>
<td>2</td>
</tr>
<tr>
<td>Cultured shrimps</td>
<td>8,181</td>
<td>9</td>
</tr>
<tr>
<td>Fresh water prawns</td>
<td>1,359</td>
<td>2</td>
</tr>
<tr>
<td>Milk fish and sea bass</td>
<td>514</td>
<td>1</td>
</tr>
<tr>
<td>Oyster and crabs</td>
<td>185</td>
<td>0.2</td>
</tr>
<tr>
<td>Sea weed</td>
<td>322</td>
<td>0.4</td>
</tr>
<tr>
<td>Sea cucumber</td>
<td>196</td>
<td>0.2</td>
</tr>
<tr>
<td>Lobster</td>
<td>19</td>
<td>0.02</td>
</tr>
<tr>
<td>Other wild fish</td>
<td>10,746</td>
<td>12</td>
</tr>
</tbody>
</table>
List of commercially important finfishes

Lists of important finfish species from freshwater, brackish water and marine water aquaculture are given below.

Important finfishes from freshwater aquaculture

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oreochromis mossambicus</td>
<td>Mosambique tilapia</td>
</tr>
<tr>
<td>Oreochromis niloticus</td>
<td>Nile tilapia</td>
</tr>
<tr>
<td>Labeo rohita</td>
<td>Rohu</td>
</tr>
<tr>
<td>Cirrhinus mrigala</td>
<td>Mrigal</td>
</tr>
<tr>
<td>Catla catla</td>
<td>Catla</td>
</tr>
<tr>
<td>Cyprinus carpio</td>
<td>Common carp</td>
</tr>
<tr>
<td>Hypophthalmichthys nobilis</td>
<td>Bighead carp</td>
</tr>
<tr>
<td>Hypophthalmichthys molitrix</td>
<td>Silver Carp</td>
</tr>
<tr>
<td>Ctenopharyngodon idella</td>
<td>Grass carp</td>
</tr>
<tr>
<td>Labeo dussumieri</td>
<td>Hirikanaya</td>
</tr>
</tbody>
</table>

Important finfishes from brackishwater aquaculture

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lates calcarifer</td>
<td>Sea bass</td>
</tr>
<tr>
<td>Chanos chanos</td>
<td>Milk fish</td>
</tr>
</tbody>
</table>

Important finfishes for marine water aquaculture

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lates calcarifer</td>
<td>Sea bass</td>
</tr>
<tr>
<td>Chanos chanos</td>
<td>Milk fish</td>
</tr>
<tr>
<td>Epinephalus sp.</td>
<td>Grouper</td>
</tr>
<tr>
<td>Lutjanus sp.</td>
<td>Snappers</td>
</tr>
<tr>
<td>Pampus argenteus</td>
<td>Silver promfret</td>
</tr>
<tr>
<td>Pagrus major</td>
<td>Sea bream</td>
</tr>
<tr>
<td>Rachycentron canadum</td>
<td>Cobia</td>
</tr>
</tbody>
</table>

Prospects of commercially important finfish aquaculture

Freshwater finfish culture

Aquaculture of Sri Lanka has been developed since mid-1970s, when the government (Ministry of Fisheries) provided subsidies for pond culture of
freshwater finfishes. After the development of male tilapia production, the farmers have expanded its commercial farming in ponds and cages. After establishment of NAQDA in 1998, the concerted effort was made for the development of inland aquaculture in the country. The tilapia farming with the use of minimum water and recirculation system was started in Gampaha district. The freshwater finfish production from aquaculture and culture-based fishery were 389.5 and 2239t, respectively during 2018.

The demand for freshwater fish is continuously increasing. There are lots of opportunities available in the country for commercial finfish farming. At present, the entire freshwater finfish produced are locally consumed and very limited quantity is available for the urban markets. There is also a huge demand of frozen tilapia as well as fish fillets in the export market. Hence, there is great opportunity to establish commercial intensive finfish farming at suitable areas. There are numerous ancient irrigation reservoirs and also newly constructed perennial reservoirs under the Mahaweli scheme are available for intensive cage farming. Plastic lining ponds could be used for intensive land based culture practices for enhancing fish production.

**Marine finfish aquaculture**

NAQDA has succeeded in sea bass breeding with public-private partnership and provided expertise to the private hatcheries. Earlier the sea bass farming was completely dependent on imported seeds. The production of 115,070 fingerlings during 2018 paved the way of sea bass farming expansion in Sri Lanka. At present the private entrepreneurs are involved in sea bass cage culture in Negombo lagoon, Mannar, Puttalam, Batticaloa and Galle. Around 350 farmers are involved in sea bass farming in cages and ponds. The sea bass production was 340t during 2018. A large scale sea bass cages farming is operational in Trincomalee Sea. The sea bass culture has supported the livelihood of coastal community, reduced pressure on wild fishery, ensured consistent supply of fish to the markets and generated export revenue. For the aquaculture of milk fish the farmers are still dependent on the wild caught post-larvae. Generally milk fish farming is also carried out by the private entrepreneurs for food fish production and also the small fish is used as bait for line fishing.

Construction of the marine finfish hatchery in Tharmapuram in Batticaloa district was also started during 2016 under the FAO sponsored project to meet the needs of marine finfish seeds in Sri Lanka. Milk fish (Chanos chanos), Barramundi/Asian sea bass (Lates calcarifer), Grouper (Epinephalus sp.), Snappers (Lutjanus sp.), Silver promfret (Pampus argenteus), Sea bream (Pagrus major), Mahi mahi (Coryphaena hippurus), and Cobia (Rachycentron
canadum) have been identified as candidate species for captive breeding. It is planned to create livelihoods (direct/indirect) opportunity for 1600 families by establishing hatcheries in coastal area to save the foreign exchange involved during imports of fish seeds.

**Ornamental finfish culture**

The ornamental fish culture industry is widespread in the island. The breeders and exporters are mainly confined to Colombo and suburbs. The breeders practice simple natural spawning techniques to breed freshwater ornamental finfishes. NAQDA is involved in the development of technology for new ornamental fish strains. The organization is responsible for providing brood fish, diagnosis of fish disease and technical assistance through training to support the development of ornamental fish industry and their exports. Aquaculture Development Centres at Rambodagalla and Ginigathena are dedicated for the ornamental fish aquaculture.

The marine ornamental fish export sector is totally dependent on the wild collection and currently over 200 marine species belonging to 40 families are being exported. Several species of wild marine fish populations have declined due to overfishing. To tide over the situation, the government of Sri Lanka has restricted export of certain marine species as well as several wild caught freshwater fish species.

Sri Lanka exports ornamental fish to more than 18 destinations. There are 66 large-scale and small-scale ornamental fish exporters in Sri Lanka. Foreign exchange earned due to export of ornamental fish was 2626 million LKR during 2018. NAQDA continued establishing ornamental fish breeding and pond farming centre at Sevanapitiya in Polonnaruwa district. Also, NAQDA has commenced establishment of a marine ornamental fish breeding centre at Bangadeniya in Puttalam district for technology verification of marine ornamental fish.

**Present hatchery production, seed rearing and aquaculture practices and production of commercially important finfish**

**Freshwater finfish seed production and rearing**

NAQDA maintains eight major aquaculture development centres for freshwater fin fish breeding, two for ornamental fish breeding and a multi species marine fin fish hatchery. Table-3 elaborates the fish species produced by NAQDA finfish breeding centers. The fry production from Aquaculture Development Centers (AQDCs) at Udawalawa, Dambulla,
Inginiyagala, Iranamadu, Muruthawela and Nuwara Eliya were 182.53 million during 2018. A major part of these fry were sold to private pond owners (PPOs). The fry were also sold to community based organizations (CBOs) and fish farmers for rearing in pens and cages to grow in to fingerling. The fry production and distribution during 2012 to 2018 is reflected in table 4. A total of 111.63 million fingerlings were produced during 2018 by AQDCs, CBOs and private farmers, which remains 35% higher compared to the fingerling production during 2017 (Table 5). The distribution of fingerlings produced is also presented in the table 6.

Table 3. Fish species produced/activity from NAQDA finfish breeding centres

<table>
<thead>
<tr>
<th>Centre</th>
<th>Fish species produced/activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Udawalawa (carp)</td>
<td>Common carp, Indian carps and Chinese carps</td>
</tr>
<tr>
<td>Dambulla</td>
<td>Common carp, Indian carps, Chinese carps and Tilapia</td>
</tr>
<tr>
<td>Inginiyagala</td>
<td>Common carp, Indian carps and Tilapia</td>
</tr>
<tr>
<td>Nuwara Eliya</td>
<td>Common carp</td>
</tr>
<tr>
<td>Udawalawa (tilapia)</td>
<td>Tilapia species</td>
</tr>
<tr>
<td>Iranamdu</td>
<td>Common carp, Indian carps, Chinese carps and Tilapia</td>
</tr>
<tr>
<td>Muruthawela</td>
<td>Common carp, Indian carps, Chinese carps and Tilapia</td>
</tr>
<tr>
<td>New Udawalawa</td>
<td>Common carp, Indian carps and Chinese carps</td>
</tr>
<tr>
<td>Rambodagalle</td>
<td>Ornamental fish breeding and conducting trainings</td>
</tr>
<tr>
<td>Ginigathhena</td>
<td>Ornamental fish breeding and rearing</td>
</tr>
<tr>
<td>Multi species marine fin fish hatchery</td>
<td>Sea bass</td>
</tr>
</tbody>
</table>

Table 4. Fry production and distribution (million) during 2012-2018

<table>
<thead>
<tr>
<th>Fry supply to different units</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini nurseries</td>
<td>10.85</td>
<td>12.52</td>
<td>6.57</td>
<td>11.90</td>
<td>15.76</td>
<td>19.13</td>
<td>26.35</td>
</tr>
<tr>
<td>AQDCs</td>
<td>40.05</td>
<td>62.74</td>
<td>55.39</td>
<td>50.79</td>
<td>57.64</td>
<td>60.82</td>
<td>79.03</td>
</tr>
<tr>
<td>PPOs</td>
<td>24.39</td>
<td>21.94</td>
<td>11.93</td>
<td>15.67</td>
<td>8.53</td>
<td>6.63</td>
<td>16.89</td>
</tr>
<tr>
<td>Cages / pens</td>
<td>1.11</td>
<td>0.84</td>
<td>2.02</td>
<td>9.95</td>
<td>30.34</td>
<td>47.20</td>
<td>60.26</td>
</tr>
<tr>
<td>Total</td>
<td>76.40</td>
<td>98.04</td>
<td>75.91</td>
<td>88.31</td>
<td>112.27</td>
<td>133.78</td>
<td>182.53</td>
</tr>
</tbody>
</table>
Table 5. Fingerling production (million) during 2012-2018

<table>
<thead>
<tr>
<th>Fingerling production</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini nurseries</td>
<td>5.63</td>
<td>5.76</td>
<td>4.27</td>
<td>7.24</td>
<td>10.30</td>
<td>13.38</td>
<td>17.20</td>
</tr>
<tr>
<td>AQDCs</td>
<td>21.18</td>
<td>34.94</td>
<td>30.94</td>
<td>39.65</td>
<td>37.29</td>
<td>38.07</td>
<td>48.20</td>
</tr>
<tr>
<td>PPOs</td>
<td>9.87</td>
<td>8.43</td>
<td>4.81</td>
<td>6.06</td>
<td>4.07</td>
<td>3.31</td>
<td>7.11</td>
</tr>
<tr>
<td>Cages / Pens</td>
<td>0.71</td>
<td>0.26</td>
<td>0.96</td>
<td>2.26</td>
<td>18.11</td>
<td>28.16</td>
<td>38.79</td>
</tr>
<tr>
<td>Total</td>
<td>37.39</td>
<td>49.39</td>
<td>40.98</td>
<td>55.21</td>
<td>69.77</td>
<td>82.92</td>
<td>111.30</td>
</tr>
</tbody>
</table>

Table 6. Distribution (stocking) of fish fingerlings in 2018

<table>
<thead>
<tr>
<th>Type of water body</th>
<th>Number of tanks/ units</th>
<th>Fingerling Stocked (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major reservoirs</td>
<td>42</td>
<td>30.06</td>
</tr>
<tr>
<td>Medium reservoirs</td>
<td>76</td>
<td>31.19</td>
</tr>
<tr>
<td>Minor reservoirs</td>
<td>288</td>
<td>32.78</td>
</tr>
<tr>
<td>Seasonal tanks</td>
<td>526</td>
<td>9.40</td>
</tr>
<tr>
<td>Villu and flood plains</td>
<td>2</td>
<td>0.70</td>
</tr>
<tr>
<td>Ponds</td>
<td>600</td>
<td>1.40</td>
</tr>
<tr>
<td>Rivers and lagoons</td>
<td>15</td>
<td>2.09</td>
</tr>
<tr>
<td>Total</td>
<td>1,549</td>
<td>107.62</td>
</tr>
</tbody>
</table>
**Marine finfish seed production and rearing**

The marine finfish breeding (sea bass) technology has been adapted by a private hatchery and a government hatchery, and produced 115,070 sea bass fingerlings in 2018. NAQDA has also commenced the construction milkfish breeding centre at Chilaw in Puttalam district. The total production of both the species during 2012 to 2018 are presented in table 7.

Table 7. Production of freshwater and marine finfish fingerlings (million) during 2012-2018

<table>
<thead>
<tr>
<th>Variety</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish Fingerling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tilapia</td>
<td>10.6</td>
<td>17.8</td>
<td>18.5</td>
<td>24.16</td>
<td>30.12</td>
<td>41.71</td>
<td>57.46</td>
</tr>
<tr>
<td>Carp</td>
<td>8.5</td>
<td>7.2</td>
<td>5.9</td>
<td>4.27</td>
<td>8.1</td>
<td>6.97</td>
<td>6.27</td>
</tr>
<tr>
<td>Catla/Rohu</td>
<td>14.5</td>
<td>18.6</td>
<td>10.1</td>
<td>16.09</td>
<td>18.7</td>
<td>21.96</td>
<td>30.23</td>
</tr>
<tr>
<td>Hiri Kanaya</td>
<td>0.2</td>
<td>-</td>
<td>-</td>
<td>0.25</td>
<td>0.23</td>
<td>0.48</td>
<td>0.47</td>
</tr>
<tr>
<td>Mirigal</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8.47</td>
<td>12.58</td>
<td>10.75</td>
<td>14.48</td>
</tr>
<tr>
<td>Sea bass</td>
<td>0.50</td>
<td>0.08</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.30</td>
<td>0.35</td>
</tr>
<tr>
<td>Total</td>
<td>38.8</td>
<td>43.8</td>
<td>37.0</td>
<td>53.5</td>
<td>70.0</td>
<td>82.17</td>
<td>109.26</td>
</tr>
</tbody>
</table>

*Figure 2. Seabass sea cages*
Ornamental fish culture industry is widespread throughout the country. Natural spawning techniques are followed for different ornamental fish by the private farmers. NAQDA is also involved in providing brood fish and seed to ornamental fish farmers as a support to achieve higher production. The ornamental fish breeding centres Rambodagalla and Ginigathena are responsible for these activities. The details of brooders and seed distribution to farmers through these centres during 2018 are shown in table 8.

### Table 8. Number of brooders and seed provided for farmers through ornamental fish breeding centres at Rambodagalla and Ginigathena in 2018

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of brooders</th>
<th>No. of seed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ornamental breeding centre - Rambodagalla</td>
<td>Ornamental breeding centre - Ginigathena</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>PL (7-10 days old)</td>
<td>Fry</td>
<td>Day-old fry (1-7 days old)</td>
</tr>
<tr>
<td>2015</td>
<td>45,907</td>
<td>8,513</td>
<td>54,420</td>
</tr>
<tr>
<td>2016</td>
<td>83,115</td>
<td>9,598</td>
<td>92,713</td>
</tr>
<tr>
<td>2017</td>
<td>86,250</td>
<td>8,457</td>
<td>94,707</td>
</tr>
<tr>
<td>2018</td>
<td>113,967</td>
<td>4,076</td>
<td>118,043</td>
</tr>
</tbody>
</table>

Aquaculture practices and production of commercially important finfishes

Freshwater finfish aquaculture in Sri Lanka is carried out in ponds, pens and cages. Open, partly closed or fully closed net cages are most common system for marine finfish farming. The use of recirculation technology for finfish farming is also practiced. However, the costs for construction and operation of recirculatory systems are higher than cage or pond farming. The aquaculture practice in the country is categorized as extensive or intensive depending on the fish density, degree of management and input level. Ornamental fish farming is usually done in cement ponds, mud ponds or glass tanks, depending on the fish variety. The production details of commercially important finfish species during 2012-2018 is presented in table 9.
Table 9. Production (t) details of commercially important finfish species during 2012-2018

<table>
<thead>
<tr>
<th>Species</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilapia</td>
<td>36,105</td>
<td>38,559</td>
<td>46,036</td>
<td>40,504</td>
<td>43,836</td>
<td>50,065</td>
<td>51,806</td>
</tr>
<tr>
<td>Rohu</td>
<td>4,052</td>
<td>3,029</td>
<td>3,949</td>
<td>3,418</td>
<td>3,356</td>
<td>2,830</td>
<td>2,933</td>
</tr>
<tr>
<td>Catla</td>
<td>6,552</td>
<td>4,789</td>
<td>6,753</td>
<td>5,699</td>
<td>4,416</td>
<td>5,605</td>
<td>6,180</td>
</tr>
<tr>
<td>Common carp</td>
<td>1,789</td>
<td>1,606</td>
<td>1,912</td>
<td>1,533</td>
<td>1,549</td>
<td>1,345</td>
<td>1,255</td>
</tr>
<tr>
<td>Big Head carp</td>
<td>115</td>
<td>52</td>
<td>121</td>
<td>114</td>
<td>62</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Silver carp</td>
<td>32</td>
<td>39</td>
<td>104</td>
<td>100</td>
<td>298</td>
<td>50</td>
<td>22</td>
</tr>
<tr>
<td>Mrigal</td>
<td>481</td>
<td>666</td>
<td>1,224</td>
<td>1,084</td>
<td>1,436</td>
<td>2,830</td>
<td>2,323</td>
</tr>
<tr>
<td>Grass carp</td>
<td>9</td>
<td>39</td>
<td>25</td>
<td>16</td>
<td>18</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Hiri Kanaya</td>
<td>627</td>
<td>614</td>
<td>580</td>
<td>358</td>
<td>230</td>
<td>330</td>
<td>298</td>
</tr>
<tr>
<td>Lula</td>
<td>1,680</td>
<td>1,991</td>
<td>2,228</td>
<td>1,582</td>
<td>1,849</td>
<td>2,765</td>
<td>1,644</td>
</tr>
<tr>
<td>Milk fish</td>
<td>40</td>
<td>35</td>
<td>25</td>
<td>5</td>
<td>31</td>
<td>60</td>
<td>122</td>
</tr>
<tr>
<td>Sea bass</td>
<td>56</td>
<td>55</td>
<td>50</td>
<td>72</td>
<td>143</td>
<td>230</td>
<td>392</td>
</tr>
</tbody>
</table>

Issues and challenges

**Environmental issues**

- Climate changes could affect the productivity of the aquaculture sector.
- Intensive aquaculture could lead to the environmental pollution, resulting environmental degradation and disease out-break.

**Social issues**

- Conflicts arise during the implementation of aquaculture activities in areas under jurisdiction of other departments and agencies.
- Sri Lanka does not have traditional aqua farming. Hence, it is difficult to establish new aqua-farming technologies with the community participation.
- The wild waters are not demarcated for aquaculture. Many times these areas create conflicts for fishing activities among different users.
- Some potential overlapping interests create conflicts in lagoons for aquaculture.
Planning and management issues

- It is experienced that investors face difficulties to obtain land permits for aquaculture due to restriction imposed by different ministries. Lengthy bureaucratic approval procedures make the private entrepreneurs frustrated and lose interest for aquaculture.

- Most of the lands suitable for aquaculture practices are paddy fields. It is difficult to convert these lands into fish ponds because of policy issues.

- Non-availability of adequate quality seeds is another major constraint of aquaculture development in the country.

- Increasing inputs cost (seed, feed, fertilizers, drugs etc.) in aquaculture reduce the margin of profit from fish culture, and restrict aquaculture expansion.

- The risk in aquaculture lowers the interest of private entrepreneurs as a business.

- Legal constraints for the use of lagoons/water bodies that are part of national parks, wildlife sanctuaries and protected wetlands.

- Lack of technology and infrastructure to breed commercially important marine species.

- Although there is an effective extension network, the number of technical/extension personnel is seemingly inadequate. It is also difficult to retain professional staff in this field of aquaculture.

- Lack of adequate ice producing facilities around the inland fish producing areas.

- Lack of availability of cost effective fish feeds and cage/pen materials for the development of aquaculture.

- Non-availability of land mapping through GPS to identify suitable areas for coastal aquaculture.

- Low rate of novel technology flow to the country from other countries.

- High costs of imported inputs for sea bass farming as well as farming of other finfish varieties.

- Low participation of private investors in the aquaculture sector because of:
  - Long application procedures for aquaculture (including all line agencies).
  - Inadequate incentives: tariff reductions/loans/ tax grace after profit achieved.
Discourages to accept 1 year licenses by investors

- Lack of clear standards/mandates/criteria of many of the advisory committees dealing with applications.
- Difficulties faced by small operators to market access.
- Inadequate research and development support.

**Issues related to export of aquaculture products**

- Sri Lanka being an island is subject to fierce competition for aquaculture products from other competitor countries in the region having economies and productions of scale.
- Effects due to external trade barriers by developed countries on the import of aquaculture products.
- The producer is getting very low price while middle men get higher profits in the export commodities. The low selling prices do not allow the producers to get higher profit margin, which results less enthusiasm for farming.
- The export of marine ornamental fish is totally dependent on the capture of wild stocks and currently over 200 marine species belonging to 40 families are being exported. This consequently led to the depletion of several wild fish populations. Government has prohibited or restricted export of certain marine and freshwater fish species. The research and development for these species are to be re-looked.

**Institutional setup and stakeholder involvement**

- The Fisheries and Aquatic Resources Act (1996) addresses the management, regulation, conservation and development of fisheries and aquatic resources in Sri Lanka.
- The National Aquaculture Development Authority of Sri Lanka Act (1998) is established to regulate its functioning and constitution, which is responsible for the development of the aquaculture sector in Sri Lanka. It has been designed to address issues pertaining to food security, employment generation, earning of foreign exchange through development and promotion of inland fisheries. The organizational structure of National Aquaculture Development Authority is shown in Fig. 3.
Figure 3. Organizational structure of National Aquaculture Development Authority of Sri Lanka
Recommendations

**Capacity building**

- Provide foreign training programme with latest knowledge, new technology and skills related to aquaculture development for the officers.

- Impart regular training programme to farmers for the knowledge gain.

**Policy development**

- Apply temporal and spatial planning in development of aquaculture.

- Allocate land and water resources for aquaculture project only after environmental, socio-economic and cultural impact assessment.

- Ensure that aquaculture projects are implemented in strict compliance with conditions of approval.

- Promote the use best management practices (BMPs) in aquaculture.

- Use of management information systems for planning, development, management and reporting.

- Utilize part of the earnings from the fisheries production in that water-body for the over-all development to assure the sustainable production.

- Expand and intensify aquaculture through environmentally friendly approaches.

- Diversify with the culture of new exotic species or genetically improve species with the application of precautionary principal, which must be in compliance with the Food and Agriculture Organization (FAO) Code of Practice.

- Ensure the safety level of locally marketed fish and fishery products for meeting nutritional requirements.

- Stock fish as buffer stocks during gluts to ensure the availability of fish at reasonable prices during lean periods.

- Ensure the traceability and transparency at all stages of the value chain process.

- Improve quality infrastructure facilities in the production and supply chain.

- Develop awareness on the best fish handling practices.

- Promote investment in export-oriented fisheries and aquaculture project.
• Promote the production of fish and fishery products meeting the food safety and quality standards acceptable in the international market, and ensure an efficient supply chain management.

• Promote the import and culture of new exotic species that have the potential for export.

• Promote the production and export of live ornamental fish

• Promote the eco-friendly or organic production of fisheries and aquaculture products, which fetch comparatively higher prices in the international market.

• Provide assistance for branding of Sri Lankan fisheries and aquaculture products.

**Livelihood**

• Expand livelihood activities by identifying new technologies in aquaculture.

• Provide training and knowledge sharing for further progress in aquaculture production along with financial assistance and infrastructure provision.

• Develop proper market channel to sale their products.

• Emphasis on the women participation in aquaculture production as livelihood activities.

**Information**

• Information on technology and recent research development on aquaculture must be up-loaded as data base, which should be updated periodically.

**Conclusion**

There is a wide scope for aquaculture development in Sri Lanka. The aquaculture production and research are picking up after the establishment of dedicated Institutions in the country. It is high time to take care of some social issues in aquaculture, appointment of trained man power, training to farmers on latest aquaculture technologies, addition of new species in aquaculture, burrowing new established technology from abroad etc. will help the country to grow and achieve a position in the world aquaculture scenario in future.
References


Chapter 5

Aquaculture of Commercially Important Finfishes in Nepal

Subhash Kumar Jha
Central Fisheries Promotion and Conservation Center (CFPCC), Kathmandu, Nepal
jhasuvas2012@gmail.com

Aquaculture scenario

Nepal is a landlocked country; three sides are surrounded by India and the north side by China. The huge topographic variation from the southern plane part to the Himalayan northern part distribute into three geographic zones from east to west-plane (Terai), mountain (hills) and the Himalayas (Rajbanshi, 2012). There are three major climatic zones-tropical (Terai), subtropical (Siwalik & Hill) and temperate (Middle mountain and high mountain Himalayas), that provide suitable platforms for the production of different agricultural commodities including fisheries species. Nepal’s aquatic resources are based on inland freshwater. Rivers, lakes, reservoirs, swamps and irrigated paddy fields are the major source of freshwater in Nepal. Approximately 5.5% of the total area of the country is occupied by different freshwater aquatic habitats, where around 232 fish species live (Gurung, 2018). In general, aquatic habitats and fish biodiversity have lots of prospects for the development of fisheries and aquaculture in the country. The aquatic resources located at different altitudes and climatic zones offer prospects for diversified fisheries and aquaculture in Nepal.

Diversified agriculture system is a typical characteristic of Nepalese aquafarming. The fisheries and aquaculture has emerged as the fastest growing agricultural sectors (Gurung, 2014). Aquaculture has a great potential due to its technical efficiency (Sharma and Leung, 1998) and high economic profitability (2-4 times) than other agricultural sub-sectors (Baral, 1992) and cash return from aquaculture increased by 16 times (Brummett, et al., 2006).

The most common fish specieses under cultivation are indigenous and exotic carps, tilapia, pangas, catfish and rainbow trout. Institutional development of aquaculture in Nepal was started almost seven decades ago but the pace of development was slow. In last decade the progress of this sector was highly commendable. The development of the sector was mainly done through key Government programs viz., fish mission, one village one product, resource
center establishment programs etc. Fish consumption in Nepal is low compared to that of poultry, pork, buff and mutton. Increasing health awareness among people has led to increase in fish consumption and aquaculture industries. Government of Nepal is also providing support to establish commercial fish farms for employment generation.

Aquaculture development in Nepal

History of Nepalese aquaculture is short though it is very difficult to frame out the time. However, catching fish from nature is being practiced since ancient time and some ponds were constructed in Baais dhara area of Balaju, Kathmandu, and few indigenous finfishes like Sahar (*Tor Putitora*) and katle (*Neolissochilus hexagonolepis*) were reared in the late 18th century during the rule of King Rana Bahadur Shah (DoFD, 2016). In Nepal aquaculture development was institutionalized in 2003 BS (1946/47 AD) by establishing fisheries unit under the Nepal Agriculture Council. This fisheries unit went through several organizational modifications while passing through the golden era of fisheries. Officially, some indigenous fish viz., Rahu, Mrigal and Catla from India were introduced in to Nepal in 1947. Government of Nepal established fisheries development center to develop aquaculture in the country and presently there are 19 such development (Giri, S. S., ed. 2017) and research centers working across the country for aquaculture development. For the first time in 1960 the Chinese finfishes, imported from the India and Israel, were distributed to our farmer for aquaculture. The success in aquaculture was achieved by implementing Integrated Fisheries Development Project in two fisheries development centres at Pokhara and Bhairahwa during 1975-1980 with UNDP assistance. During 1981-1992 another Aquaculture Development Project was implemented with ADB and UNDP assistances. These projects boosted the aquaculture industry in the country. At the same time, rainbow trout were imported and Natural Water Fisheries Development project was started, that pave the way for establishment of the cold water aquaculture in Nepal (CFPCC, 2018/19). In 2006, the area specific program ‘one village one product’ was lunched, which focused on feasibility based commodity at specific place. With the success of this program, in 2007/08 Fish Mission program was started. Recently, the Government of Nepal has implemented a mega project, Prime Minister Agriculture Modernization Project (PMAMP) under the agriculture sector in which fisheries is focused as the rapid economic growth making commodity, with value chain approach from pond to plate. This project emphasizes problem and demand based programs on the suitable commodity of feasible area.
**Status of finfish aquaculture and fisheries**

Nepalese aquaculture is in growing stage and the quantum of fish production is too low compared to the world aquaculture production. The pond aquaculture with common carps, Chinese and Indigenous Major carps significantly contribute to the average productivity of 4.91 t/ha. The monoculture of common carp, tilapia and catfish are also practiced in few places of the country. At present aquaculture has expanded to 55 districts out of total 75. A decade ago aquaculture was restricted in 30 districts only (Kunwar and Adhikari, 2018). The carps polyculture technology in ponds has been widely disseminated recently in the southern plain areas and mid-hill parts of the country and become the viable and common aquaculture activity, which alone generated 67.52% (58,433 t) of the total aquaculture production in 2017/18 (CFPCC, 2017/18) (Table 1). Intensive farming of *Cirrhinus mrigala* under single stocking and multiple harvesting to produce smaller size fish, called Chhadi, is also a successful farming system in Nepal. The pond production system has been categorized into the extensive, semi-intensive and intensive level.

Table 1. Aquaculture production in Nepal in 2017/18 (CFPCC, 2017/18)

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Pond (nos.)</th>
<th>Total Area (ha)</th>
<th>Fish Production (t)</th>
<th>Productivity (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquaculture production</td>
<td>-</td>
<td>-</td>
<td>65,544</td>
<td>-</td>
</tr>
<tr>
<td>Pond Fish culture</td>
<td>44,725</td>
<td>11,895</td>
<td>58,433</td>
<td>4.9</td>
</tr>
<tr>
<td>Other area (swamps)</td>
<td>-</td>
<td>3,550</td>
<td>6,390</td>
<td>1.8</td>
</tr>
<tr>
<td>Cage fish culture (m³)</td>
<td>-</td>
<td>71,800</td>
<td>302</td>
<td>4.2 kg/m³</td>
</tr>
<tr>
<td>Trout Fish Culture in Raceway</td>
<td>-</td>
<td>3.20</td>
<td>320</td>
<td>100</td>
</tr>
<tr>
<td>Others (Govt. Farm, Paddy cum fish culture and enclosure)</td>
<td>-</td>
<td>98.8</td>
<td>100</td>
<td>1.01</td>
</tr>
<tr>
<td>Capture Fisheries production</td>
<td>-</td>
<td>-</td>
<td>21,000</td>
<td>-</td>
</tr>
<tr>
<td>Total Fish Production (t)</td>
<td>-</td>
<td>-</td>
<td>86,544</td>
<td>-</td>
</tr>
</tbody>
</table>

Total annual production of fish in the country has been increased from 3,530 t in 1981/82 to 86,544 t in 2017/18, while there has been a significant increase in the annual per capita fish production from 0.33 kg in 1982 to 3.01 kg in 2017/18 (CFPCC, 2017/18).
Aquaculture is the fastest growing agricultural sectors in the last three decades with an annual growth of nearly 11.6% (Wagle et al., 2011). Aquaculture in Nepal contributes about 1.13% and 4.18% of Gross Domestic Production (GDP) and Agriculture Gross Domestic Production (AGDP), respectively. Never the less, climate change, extreme weather events, competition for water use, rapid urbanization, land fragmentation, over or illegal exploitation of fishery, low aquaculture productivity, undermining of aquaculture in national plan and policies are compounding challenges to the sustainability of inland aquaculture. Increasing aquaculture production in the country has significantly contributed to the national food supply as well as economic development. The demand for aquaculture and fisheries to provide fish is increasing in the country, and the demand for fish is very high in comparisons to the production level.

Capture fisheries production in Nepal is 21000 t (Table 2). There are 448,733 people engaged in capture fisheries, of which 59% are women. The women are also engaged in preparing fishing gears, equipment, fishing and selling fish in the market.
Table 2. Status of capture fisheries production in Nepal in 2017/18 (CFPCC, 2017/18)

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Total Area (ha)</th>
<th>Fish production (t)</th>
<th>Productivity (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquaculture production</td>
<td></td>
<td>65,544</td>
<td>-</td>
</tr>
<tr>
<td>Capture fisheries production</td>
<td></td>
<td>21,000</td>
<td>-</td>
</tr>
<tr>
<td>Rivers</td>
<td>395,000</td>
<td>7,110</td>
<td>18</td>
</tr>
<tr>
<td>Lakes</td>
<td>5,000</td>
<td>1000</td>
<td>200</td>
</tr>
<tr>
<td>Reservoirs</td>
<td>1,500</td>
<td>525</td>
<td>350</td>
</tr>
<tr>
<td>Swamps</td>
<td>9,000</td>
<td>5,200</td>
<td>578</td>
</tr>
<tr>
<td>Low land irrigated paddy fields</td>
<td>398,000</td>
<td>7,165</td>
<td>18</td>
</tr>
<tr>
<td>Total fish production</td>
<td></td>
<td>86,544</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 2. Fish production trend by aquaculture and capture fisheries

List of commercially important finfishes

Two hundred and thirty indigenous fish species, belonging to 11 orders, 34 families and 104 genera are reported in Nepal, (Rajbansi, 2012). Among them 16 are endemic species, and many are economically important food, game and recreational fish that support the small-scale fisheries as well as capture fisheries sector and plays a key role in up lifting the rural livelihood.

Fish farming has been traditionally practiced by some tribes in Nepal since time immemorial. Generally, Tharu, Kewat, Das, Kahar, Mallaha, Lodh, Gaud, Gaha, Gurung, Kumal, Gupta and Magar tribes are traditionally involved in capture fishery (Dahal et al., 2013) for their livelihood and food sources (Rajbanshi et al., 2002). With the development of aquaculture
technology in Nepal there are numbers of commercially important finfishes cultured in Nepal.

As landlocked country, freshwater finfish aquaculture and the related technology are widely adopted in the country. The aquaculture system of Nepal is mainly categorized into five types depending upon waterbodies and physical facilities viz., (1) fish culture in ponds, (2) fish culture in wetlands, (3) fish culture in enclosures or pens, (4) fish culture in cages and (5) fish culture in raceways (Figure 3) of cold water fish culture (Giri, S. S., ed. 2017), and the aquaculture practices are broadly categories in to: extensive, semi-intensive and intensive aquaculture systems.

Figure 3. Raceways for cold water aquaculture in Nepal

Several indigenous and exotic fish species are farmed for food and recreational purposes. The three major Indian carps commonly farmed are Rohu (*Labeo rohita*), Catla (*Catla catla*) and Mrigal (*Cirrhinus mrigala*). In addition, exotic carps, Common carp (*Cyprinus carpio*), and Chinese carps: Grass carp (*Ctenopharyngodon idella*), Silver carp (*Hypophthalmicthys molitrix*) and Bighead carp (*Aristichthys nobilis*) have been cultured since 1955/56 (Table 3). Recently, goldfish (*Carassius auratus*) is introduced in aquaculture as a recreational species (Shrestha, 1999). Cold water fish rainbow trout (*Oncorhynchus mykiss*) was introduced in the country from India in 1968 and 1971, and from Japan in 1988 (Shrestha, 1999). At present rainbow trout farming is done in eleven districts, Mustang, Manang, Rasuwa, Nuwakot, Sindhupalchok, Lalitpur, Kathmandu, Makwanpur, Dhading, Kavre, and Kaski (Joshi, 2014). Also, recently Nile tilapia (*Oreochromis niloticus*), Java barb (*Barbomyrus gonionotus*) and giant river prawn (*Machrobrachium rosenbergii*) are introduced in aquaculture to study their commercial production potential (Shrestha, 1999). Three high-valued indigenous coldwater fish species popular for their delicacies: Asala (*Schizothorax* sp.), Katle (*Acrosochielus* sp.) and Mahseer (*Tor* sp.) are also under consideration for commercial farming.

Nepal has a wide range of water resources as well as physiographic regions, from tropical plans to snowy covered Himalayas, that has potential to have
diverse species to grow. The natural waters like, rivers, lakes, reservoirs etc. has only few finishes that has good growth performance in farming in confined water as well as the breeding activity with well-established market which are listed mainly as commercially finishes.

The finishes with good growth performance and breeding ability in confined waters with high market demands are listed below.

Table 3. List of commercially important finishes for freshwater aquaculture (CFPCC, 2017/18)

<table>
<thead>
<tr>
<th>Fish Species</th>
<th>Scientific name</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common name</td>
<td>Scientific name</td>
<td>Domain</td>
</tr>
<tr>
<td>Rohu</td>
<td><em>Labeo rohita</em></td>
<td>Warm water, Terai</td>
</tr>
<tr>
<td>Naini</td>
<td><em>Cirrhinus mrigala</em></td>
<td>Warm water, Terai</td>
</tr>
<tr>
<td>Catla</td>
<td><em>Catla catla</em></td>
<td>Warm water, Terai</td>
</tr>
<tr>
<td>Sahar, Mahseer</td>
<td><em>Tor putitora</em></td>
<td>Cold &amp; warm water, Terai, Midhills</td>
</tr>
<tr>
<td>Asla</td>
<td><em>Schizothorax sp.</em></td>
<td>Cold water, midhills</td>
</tr>
<tr>
<td>Gold fish</td>
<td><em>Carassius auratus</em></td>
<td>Warm water, Terai, mid-hills</td>
</tr>
<tr>
<td>Katle</td>
<td><em>Acrossochielus sp.</em></td>
<td>Cold water, mid-hills</td>
</tr>
<tr>
<td>Common carp, German carp</td>
<td><em>Cyprinus carpio var. communis</em></td>
<td>Warm water, Terai</td>
</tr>
<tr>
<td>Common Carp, Israeli carp</td>
<td><em>Cyprinus carpio var. specularis</em></td>
<td>Warm water, Terai</td>
</tr>
<tr>
<td>Silver Carp</td>
<td><em>Hypophthalmichthys molitrix</em></td>
<td>Warm water, Terai</td>
</tr>
<tr>
<td>Bighead Carp</td>
<td><em>Aristichthys nobilis</em></td>
<td>Warm water, Terai</td>
</tr>
<tr>
<td>Grass Carp</td>
<td><em>Ctenopharyngodon idella</em></td>
<td>Warm water, Terai, mid-hills</td>
</tr>
<tr>
<td>Rainbow Trout</td>
<td><em>Oncorhynchus mykiss</em></td>
<td>Cold water, mid-hills</td>
</tr>
<tr>
<td>Pangasius</td>
<td><em>Pangasianodon hypophthlmus</em></td>
<td>Warm water, Terai</td>
</tr>
<tr>
<td>Nile Tilapia (GIFT)</td>
<td><em>Oreochromis niloticus</em></td>
<td>Warm water, Terai</td>
</tr>
<tr>
<td>Silver barb</td>
<td><em>Puntius goniaionotus</em></td>
<td>Warm water, Terai</td>
</tr>
</tbody>
</table>

Table 4. Finfish species that are allowed to culture after legal authority (CFPCC, 2017/18)

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Local Name</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Clarias gariepinus</em></td>
<td>African Catfish</td>
<td>Mangur</td>
<td>Warm Water</td>
</tr>
<tr>
<td><em>Pampus chinensis</em></td>
<td>Butter fish</td>
<td>Rupchanda</td>
<td>Warm Water</td>
</tr>
</tbody>
</table>
Table 5. List of commercially important indigenous finfishes, breed artificially (CFPCC, 2017/18)

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Local Name</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schizothorax plagiostomus</td>
<td>Blunt-nosed snow trout</td>
<td>Bucche Asala</td>
<td>Cold Water</td>
</tr>
<tr>
<td>Schizothoraiichthys progastus</td>
<td>Point-nosed snow trout</td>
<td>Chuchhe Asala</td>
<td>Cold Water</td>
</tr>
<tr>
<td>Tor putitora</td>
<td>Golden Mahseer</td>
<td>Pahelo Sahar</td>
<td>Cold/Warm Water</td>
</tr>
<tr>
<td>Tor tor</td>
<td>Deep-bodied Mahseer</td>
<td>Falame Sahar</td>
<td>Cold Water</td>
</tr>
<tr>
<td>Neolissocheilus hexagonolepis</td>
<td>Copper Mahseer</td>
<td>Katle</td>
<td>Cold Water</td>
</tr>
<tr>
<td>Labeo dero</td>
<td>River carp</td>
<td>Gardi</td>
<td>Cold/Warm Water</td>
</tr>
<tr>
<td>Labeo pangusia</td>
<td>River carp</td>
<td>Hade</td>
<td>Cold/Warm Water</td>
</tr>
<tr>
<td>Labeo angra</td>
<td>River carp</td>
<td>Thend</td>
<td>Cold/Warm Water</td>
</tr>
<tr>
<td>Changunius changunio</td>
<td>Chaguni</td>
<td>Rewa</td>
<td>Cold/Warm Water</td>
</tr>
<tr>
<td>Labeo calbusa</td>
<td>Calbusa</td>
<td>Calbusa</td>
<td>Cold/Warm Water</td>
</tr>
<tr>
<td>Heteropneustes fossilis</td>
<td>Singhi</td>
<td>Singhi</td>
<td>Warm Water</td>
</tr>
</tbody>
</table>

Table 6. List of ornamental finfishes artificially bred (CFPCC, 2017/18)

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carasius carassius</td>
<td>Gold Fish</td>
</tr>
<tr>
<td>Cyprinus carpio</td>
<td>Koi Carp</td>
</tr>
<tr>
<td>Poecilia reticulate</td>
<td>Guppy</td>
</tr>
<tr>
<td>Xiphophorus hellerii</td>
<td>Sword Tail</td>
</tr>
<tr>
<td>Xiphophorus maculatus</td>
<td>Platty</td>
</tr>
</tbody>
</table>

| Native       | Kolisa     |

Prospects of commercially important finfish aquaculture

Rivers, streams, lakes, reservoirs, ponds, marginal swamps and irrigated paddy fields are the major aquatic resources in Nepal. Rivers occupy 48%, lakes and reservoirs occupy 0.8% and swamps and paddy field occupy 49% of the total water area. These open water bodies occupy about 5.5% of the total area of the country.
Koshi, Gandaki and Karnali are the major rivers in Nepal with 21 tributaries. Mechi, Kankai, Kamala, Bagmati, West Rapti, Babai and Mahakali are medium sized rivers. It is estimated that the water surface in rivers is about 395,000 hectares. The estimated water surface area of the lakes is about 5000 ha. The estimated area of reservoir made for hydropower generation is about 1500 ha. It is estimated that there are about 12,500 ha marginal swamps. These swamps have good potential for aquaculture development. The pond area is estimated to be 11,896 ha and number of ponds are 44,722 (CFPCC, 2017/18). The rice fields potential for fish culture are estimated about 398,000 ha. The country’s water ecosystems offer excellent habitats to 13 exotic fish species (1 cold water species and 12 warm water species) and 230 indigenous fish species (Rajbanshi, 2012) of high economic, environmental and academic value.

The Chinese carps and Indian major carps are the dominant species in pond aquaculture with average productivity of 4.91 t/ha. These species are generally stocked under poly-culture system. However, monoculture of Common carp, Tilapia and Pangasius has also been reported. The Chhadi fish culture is very successful and popular in eastern Terai, and also gaining popularity in other regions of Nepal. Farmers have reported Chhadi fish production is as high as 12-15 t/ha. Such finger sized fish are of high demand in hotels and restaurants mainly on highways.

Second contributor in fish production is Ghol. About 3550 ha Ghols are used for aquaculture, with 6390 t fish production in 2017/18. The cage culture technology was used for the first time in 1962 in lake Phewa for raising common carp brood fish. Current data shows that cages occupy 71,800 m³ with production of 302t (CFPCC, 2017/18) and average productivity of 6 kg/m³. This is proven as the best method of income generation for land less
fishermen communities. In lake Phewa about 90 Jalari families have landed their cages which is a reliable source of income to sustain their family. However, cage culture is confined to only few lakes of Pokhara valley and Kulekhani reservoir that need to be extended to other potential water bodies as well.

Out of total 230 indigenous fish species a number of economically importance finfishes are commonly used for game fishes for aqua-tourism, and also as high valued indigenous species as delicacies (Table 7). These economically important fishes have specific characters to have their specific market value.

Table 7. Economically important food and Game fishes (Shrestha, 2005)

<table>
<thead>
<tr>
<th>Local name</th>
<th>Scientific name</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chuche Asla</td>
<td><em>Schizothorax progastus</em></td>
<td>Cold water</td>
</tr>
<tr>
<td>Sahar (Kalo Sahar)</td>
<td><em>Tor tor</em></td>
<td>Cold &amp; warm water</td>
</tr>
<tr>
<td>Sahar (Pahelo Sahar), Ratar</td>
<td><em>Tor putitora</em></td>
<td>Cold &amp; warm water</td>
</tr>
<tr>
<td>Gardi or Thed</td>
<td><em>Labeo angra</em></td>
<td>Cold &amp; warm water</td>
</tr>
<tr>
<td>Karsa</td>
<td><em>Labeo gonius</em></td>
<td>Cold &amp; warm water</td>
</tr>
<tr>
<td>Banga or Thed</td>
<td><em>Labeo dero</em></td>
<td>Cold &amp; warm water</td>
</tr>
<tr>
<td>Bata</td>
<td><em>Labeo bata</em></td>
<td>Cold &amp; warm water</td>
</tr>
<tr>
<td>Karnoch or Bishari</td>
<td><em>Labeo calbasu</em></td>
<td>Cold &amp; warm water</td>
</tr>
<tr>
<td>Saur or Saul or Bhoura</td>
<td><em>Channa marulius</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Buhari</td>
<td><em>Wallago attu</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Gaichi</td>
<td><em>Macrognathus aculeatus</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Banai</td>
<td><em>Mastacembelus armatus</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Tenger</td>
<td><em>Mystus tengara</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Jalkapoor or Pottasi</td>
<td><em>Clupiso magarua</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Jalicapoor</td>
<td><em>Pseudeutropius goonawaree</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Moi</td>
<td><em>Notopterus chitala</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Chuncha Bam or Kauwa</td>
<td><em>Xenentodon cancila</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Mugri</td>
<td><em>Clarias batrachus</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Singhi</td>
<td><em>Heteropneustes fossilis</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Bachwa</td>
<td><em>Eutropiichthys vacha</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Pabata</td>
<td><em>Pangasius pangasius</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Tenger, Kanti</td>
<td><em>Mystus seenghala</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Voktari</td>
<td><em>Ompok bimaculatus</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Rewa</td>
<td><em>Chagunius chagunio</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Raj Bam</td>
<td><em>Anguilla bengalensis</em></td>
<td>Warm water</td>
</tr>
<tr>
<td>Gouch or Thed</td>
<td><em>Bagarius bagarius</em></td>
<td>Cold &amp; Warm water</td>
</tr>
</tbody>
</table>
**Development trend**

Finfishes are the major aquaculture species in Nepal. Very less and unrecorded number of indigenous aquatic animals and plants contribute to as aquatic products. Development in aquaculture has increased with the introduction of new technology and the species. Introduction of the rainbow trout increased the cold-water fish production in the country. The monoculture has developed with introduction of Tilapia and Pangas. Innovation of Chhadi fish technology has substantially added to the national fish production, and the technology is increasing rapidly. It has been increased by more than five folds during last 18 years from 17100 t in 2001/02 to 65544t in 2017/18.

**Expansion of pond area**

Aquaculture sector in Nepal has become good money earning agriculture sub-sector. Earlier, the farmers were not interested in this sector due to high investment cost, but in later days many programs and projects were operated that helped and facilitated aquaculture in the country. Now a days Government of Nepal is providing subsidy for the construction of ponds, which reduced the initial input cost in aquaculture. In 2015/16 large numbers of ponds were constructed (734 ha). Pond fish culture is dominant in Terai belt but its expansion in hill regions has also accelerated after implementation of pond expansion program in mid-hill districts since the fiscal year 2011/12.

![Figure 5. Trends in expansion of pond area](image)
Present hatchery production, seed rearing and aquaculture practices and production of commercially important finfishes

Seed is the most important input in aquaculture. At the beginning of the aquaculture practices in the country there were very few fish hatchery and nursery and also there were very less demand of fish seeds. With the expansion of aquaculture, the number of hatchery as well as nursery increased. In Nepal fish seed are available as hatchlings, fry and fingerlings. Both public and private sectors are responsible for seed supply. There are 14 governments and 83 private hatcheries, 235 nursery and 30 fish seed traders working in Nepal.

![Fish seed production trend in private and public sector](image)

In last decade seed supply by the public sector remained constant, while the seed supply by the private sector has jumped from 5.7 million in 2001/02 to 220 million in 2017/18. This is because government has given priority to private sector in seed supply. To empower private sector, various supportive programs are being launched viz., establishing fish seed resource centers under private ownership.

Table 8. Status of fish seed production in 2017-2018 (CFPCC, 2017/18)

<table>
<thead>
<tr>
<th>Fish seed (Fry) Production/Distribution (No. in '000)</th>
<th>295,130</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Sector</td>
<td>75,505</td>
</tr>
<tr>
<td>a. Hatchling*</td>
<td>257,425</td>
</tr>
<tr>
<td>b. Fry</td>
<td>18,037</td>
</tr>
<tr>
<td>c. Fingerling</td>
<td>16,650</td>
</tr>
<tr>
<td>Private Sector (Fry)</td>
<td>220,625</td>
</tr>
</tbody>
</table>

*Hatchling of public sector is distributed for fry production in private sector
Hatchery management system of finfishes in Nepal

Hatchery management for seeds production for carps is mainly done in warm water and rainbow trout in cold water aquaculture. Well established public and private farms focus to produce hatchling and fry by semi-artificial breeding and artificial breeding of common carp, Chinese carp and indigenous major carps.

Few hatcheries are producing mono-sex tilapia fry by using 17-α methyl testosterone but still facing problem for production of 100% male tilapia. In case of pangas, farmers are still using seed imported from Bangladesh and India. Research are ongoing for mass seed production of pangas.

Recently, sahar, also called as golden mahseer have good performance of breeding in warm water condition. Successful breeding performance of sahar gives the new platform for the incorporation of new species in carp polyculture in Nepal. Sahar breeding was well established in cold water sub-tropical climate of Nepal and has recently get success breeding in tropical condition (Jha et al., 2017) which will influence and increase the species for ranching program and promote the aqua tourism in Nepal.

In context of cold water, only the rainbow trout has its significant amount of seed production in public and private sector at Nuwakot, Rasuwa, Trisuli, Kaski. The major seasons for the trout breeding are November to January. After breeding at one place eyed-egg are transfer to another place for rearing and production.

Seed rearing (Nursery management) system of finfishes

The hatchling are reared for one month to get carp fry. The nursery stage management is more technical and tedious. Nursery rearing is done mostly in earthen ponds. The nursery ponds are generally small in size and not more than 500-700 m². Fry rearing ponds are up to 700-1300 m² size. Stocking rate of hatchling and fry are 450 hatchling/m² and 35-40 fry/ m², respectively.

Figure 7. Carp Nursery at Kailali District
Aquaculture practices and production system of commercially important finfishes

Recommended technologies for carp polyculture in pond

- Soil: loam, clay loam
- Slope: 1:2
- Species: 7 (Common carp 25%, Silver carp 35%, Bighead carp 5%, Grass carp 5%, rohu 10%, Naini 15%, bhakur 5%)
- Stocking time: February to March
- Stock rate: 12,000 fingerling/ha
- Stock size: Fingerling 10-25 g
- Feed: 3% of total biomass/day, contain 25-30% protein, normally rice brain and oil seed cake are used. Sometimes pellet feeds are also used.
- Manure: 3000kg/year
- Nitrogen: 220kg
- Phosphorus: 345kg
- Culture period: 300 days
- Culture practice: Multiple stocking and multiple harvesting
- Regular water quality checking: pH 6.5-9, temp. 18-32°C, turbidity 40 cm, DO above 5ppm
- Lime: 500kg/ha
- Aerator
- Production: above 5t/ha

Raceway culture

- There is only one species of cold water aquaculture mainly Rainbow trout (Oncorhynchus mykiss) is cultured in monoculture system with the practice of intensive farming.

The recommended technologies of Rainbow trout culture are as follows:

- Pond: raceway 10 m length, 1.5 m with and 1 m depth
- Stocking time: March to February.
- Stocking rate: 40-50 fingerlings/m³
• Feed: 5% of total biomass/day, 40-50% protein content, pellet feed according to fish size
• Culture period: 14-15 month
• Water qualities: water color clear, temp. 8-18°C,
• Water flow: 1 lit/sec
• Production: 100t/ha

Figure 9. Rainbow trout farming

Issues and challenges

Environmental issues
• The capture fisheries have not significant progress in fisheries production
• Every year fisheries catch and indigenous fish species are declining
• Habitat of aquatic life and breeding space are getting destroyed by human intervention
• Most of the rivers and other natural water resources are having low catch per unit area of local indigenous species (eg. Sahar Tor tor, Tor putitora, Asala Schizothorax sp, Katle Neolisocheilus hexagonolepis etc) year after year due to illegal and unmanaged way of fishing.
• EIA reports are not focused in aquatic life conservation
• Aquaculture affected by the degraded soil at mid-hills
• Brood collection and exchange program are not good due to less catch of indigenous species in natural water
• “Aquatic animal protection Act” has no implementation properly

Social issues
• Less adoption of new technology in aquaculture
• Specific species are the main acceptance in certain community
• Though aquaculture is a profitable business still-youth are not interested to build their carrier in this sector
• Social taboos as the aquaculture business is only for certain community
• Good and hard workers are not promoted due to the less access in administration and local government
Planning and management issues

- Government of Nepal focused on more subsidy program for the construction of new ponds and hatchery
- Lack of community based programs
- Less involvement of stakeholders
- Less focused program for the value chain of fisheries sector
- The burning issues of pangas and tilapia mass seed production is not focused by the government
- Fish seed quality assessment is poor
- Fish market and post-harvest sector of fish is poor

Issues related to the export of aquaculture product

- As Nepal is not self-sufficient in aquaculture sector, so every year 10,756 t fish is imported in the country
- Problem inside the country are lack of proper internal transportation
- Post-harvest sector is not yet focused in planning of program

Institutional setup and stakeholder involvement

The fisheries and aquaculture are one of the important commodity development program of Government of Nepal. The program is carried out through the Central Fisheries Promotion and Conservation Center (CFPCC), under the Department of Livestock Services. It centre is responsible for central level policy framing, planning, monitoring and supervision, database, regulatory functions etc. It also coordinates with national and international fisheries and aquaculture related institutions and programs. There are three centers under the CFPCC:

- Fisheries Technology Validation and Human Resources Development Center, Janakpur
- Natural Water Fisheries Promotion and Conservation Center, Hetauda
- Fisheries Pure Line Breed Conservation and Promotion Resource Center, Bhairahawa

Natural Water Fisheries Promotion and Conservation Center, Hetauda has been mandated for capacity enhancement to fisher communities, conducting awareness on conservation of aquatic resources and utilization of natural water bodies in aquaculture promotion.

There are seven provincial Directorate of Livestock and Fisheries (DLF) one each in seven provinces, responsible for carrying out Livestock and Fisheries program, regulatory functions within the province and coordination between
federal and local level institutions. Under DLF, there are forty-seven Veterinary Hospital and Livestock Services Expert Centers (VHLSECs). Out of forty-seven VHLSECs, twenty-one have fisheries technician, who are responsible for carrying out aquaculture and fisheries extension program within their respective districts. Likewise, there are seven provincial Fisheries Development Centers (FDCs), mandated for fish seed production and distribution, technical support services and basic laboratory services. Under the same provincial DLF, there are seven livestock services training centers, mandated for the technical support and capacity development of livestock services as well as fisheries technicians.

Figure 10. Institutional Frameworks for Fisheries and Aquaculture in Nepal
Other institutions are also involved in fisheries and aquaculture development in the country. Nepal Agriculture Research Council (NARC) as autonomous body under the Ministry of Agriculture and Livestock Development, Government of Nepal, conducted core research on the aquaculture sector. There are few fisheries research centers at different geographical locations under the Fisheries Research Division of NARC: Tarahara, Parwanipur and Nepalgunj focus on warm water aquaculture, Pokhara concentrates on lake and reservoir fisheries and aquaculture research, Trishuli and Dhunche on cold water aquaculture research, and Kaligandaki on riverine species.

Table 9. Fisheries Research Center under the NARC

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of Centres</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Fisheries Research Division, Godavari, Lalitpur</td>
</tr>
<tr>
<td>2.</td>
<td>Fisheries Research Center, Pokhara, Kaski</td>
</tr>
<tr>
<td>3.</td>
<td>Fisheries Research center, Trishuli, Nuwakot</td>
</tr>
<tr>
<td>4.</td>
<td>Rainbow trout Fisheries Research Center, Dhunche, Rasuwa</td>
</tr>
<tr>
<td>5.</td>
<td>Kali Gandaki Fisheries Hatchery, Beltari, Syangja</td>
</tr>
<tr>
<td>6.</td>
<td>Regional Agriculture Research Center, (Fisheries Research Unit), Tarhara, Sunsari</td>
</tr>
<tr>
<td>7.</td>
<td>Regional Agriculture Research Center (Fisheries Research Unit), Parwanipur,bara</td>
</tr>
<tr>
<td>8.</td>
<td>Regional Agriculture Research Center (Fisheries Research Unit), Khajura, Banke</td>
</tr>
</tbody>
</table>

Scientific research is carried out by the Nepal Academy for Science and Technology (NAST). There are two departments namely, Department of Aquaculture and Department of Aquatic Resources under Agriculture and Forestry University (AFU).

Every year 15 B.Sc. Fisheries and 9 M. Sc. fisheries students are graduated from Agriculture and Forestry University. Tribhuvan University (TU), Kathmandu University (KU), Purbanchal University, Pokhara University and associated institutions also provide basic fisheries and aquaculture education to develop skilled and semi-skilled manpower for the promotion of fisheries and aquaculture in the country. Nepal Fisheries Society (NEFIS), a professional organization of fisheries and aquaculture experts has the role on technical partnership with governmental and non-governmental organization on different fields of fisheries and aquaculture.

Fish Growers Association and Fisheries Cooperatives have been contributing for social mobilization, enhanced production and promotion of fisheries and
aquaculture. National Parks under the Department of National Parks and Wildlife Conservation are carrying out conservation of aquatic resources. Nepal has limited manpower in the area of fisheries and aquaculture. There are about 300 manpower working on research (54), education (35) and extension and development (211) activities. Also, few other fisheries and aquaculture experts are working in NGOs and INGOs.

Recommendations

Capacity building

- Aquaculture is the emerging and rapid growing sector in Nepal but due to lack of adequate skilled manpower this sector is not raised to its potential
- Species specific experts as well as experts in all field of aquaculture and modern laboratories are necessity for the growth of aquaculture industry

Policy Development

- Aquaculture programs should be developed on the basis of demand
- Act to protect Aquatic Animals is necessary to conserve vast fish biodiversity
- Post-harvest sector needs to be strengthened

Livelihood

- Small-scale aquaculture and small-scale farmer should be promoted by the proper planning and should be included in National plan
- Community based program is the best way for upliftment of livelihood

Information

- The very important part for planning in right way is to be right information dissemination to farmers and to get right information of demand from the farmers

Conclusions

Aquaculture is a blooming sector in Nepal. Realizing its importance and potential, aquaculture is receiving attention from each and every corner. The increment in budget allocation in demand base programs should be the government’s priority. The technical manpower in the country is inadequate to represent aquaculture of 21st century. Specialized trainings and studies in
specific field like breeding, disease, nutrition, genetics and water quality is required. Strong interaction and cooperation between development, research and education organizations is needed to promote aquaculture and fisheries program effectively and efficiently. Ghols are the second contributor in fish production but only 26.4% of them are used in aquaculture, therefore, proper planning and management is required for the optimal utilization in fish production in ghols. Nepal has great potential for trout. Therefore, identifying cost effective construction of raceways is required to attract more and more farmers towards trout culture in future. Mechanization, feed and seed supply, post-harvest and fish market are the main area of intervention from government for considerable progress of aquaculture. Highly profitable, locally initiated Chhadi and Pangasius farming should be institutionalized by the government extension system. National policy is needed to guide and utilize vast and diversified water resources for fish production.

References


Chapter 6

Aquaculture of Commercially Important Finfishes in Bhutan

Drukpola
National Research & Development Centre for Aquaculture (NR&DCA)
Department of Livestock (DoL) Ministry of Agriculture & Forests (MoAF)
Gelephu-Sarpang, Bhutan
drukpola@moaf.gov.bt

Aquaculture scenario

Aquaculture is the fastest growing segment of agriculture (FAO, 2016). Worldwide aquaculture production has reached 110.2 million MT (MMT) in 2016, an increase of 5.2 MMT relative to the 2015 production, with an estimated value of US$ 243.5 billion. Aquaculture sector became the prospective contributors to global nutrition and food security with mean annual growth rate of 6.6%. It is estimated that by the year 2020 an additional of 23 MMT fish is required to meet the growing demand of aquaculture and its product, to maintain at least about 20 kg per capita fish consumption (FAO, 2016).

Aquaculture in Bhutan has started to gain momentum since early 2000s. Annual fish productions of 222.518 t in 2017 are produced from freshwater sources. According to NR&DCA’s database, Bhutan possesses about 40.74 ha of ponds and about 661 numbers of tanks. All of these water bodies are under aquaculture that accounts for 100% of the total fish production in the country. Non-native carps (Catla catla, Labeo rohita, Cirrhinus mrigala, Cyprinus carpio, Hypophthalmichthys molitrix and Ctenopharyngodon idella) are the mainstay of aquaculture in the country.

As per Thinley (2017) the average Bhutanese fish farm’s productivity is low which is related to poor culture management practices. FAO estimated that one acre of fish farm under optimum condition is capable of producing 4.0 t of fish in 6 months. Whereas, the current mean productivity of Bhutanese fish farm is about 1.4t (Thinley et al., 2018). Therefore, there is urgent need for commercialization of aquaculture farm and vast scope for fish production in the country.
Table 1. Fresh fish production and imports of Bhutan

<table>
<thead>
<tr>
<th>Year</th>
<th>Fish Production (t)</th>
<th>Import (Thousand tons)</th>
<th>Pond size (acres)</th>
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<tr>
<td>2007</td>
<td>1.34</td>
<td>0.76</td>
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<tr>
<td>2008</td>
<td>12.88</td>
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<td>2009</td>
<td>32.19</td>
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<td>23.12</td>
<td>0.83</td>
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<td>53.83</td>
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<td>74.25</td>
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<tr>
<td>2012</td>
<td>64.32</td>
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<td>2013</td>
<td>54.66</td>
<td>1.41</td>
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</tr>
<tr>
<td>2014</td>
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<td>96.53</td>
</tr>
<tr>
<td>2017</td>
<td>222.52</td>
<td>1.31</td>
<td>96.53</td>
</tr>
</tbody>
</table>

**List of commercially important finfishes**

Located in between two Asian giants, aquaculture sector in Bhutan is predominant with fresh water species with six species of carps being the main stay of aquaculture industry in Bhutan. Following non-native carps contribute for major chunk of freshwater domestic fish production in country.

i. *Catla catla*
ii. *Labeo rohita*
iii. *Cirrhinus mrigala*
iv. *Cyprinus carpio*
v. *Hypophthalmichthys molitrix*
vi. *Ctenopharyngodon idella*

Apart from these meager portions of domestic fresh fish production is being contributed by native species which has not gained much commercial value but much effort has been put for conserving them in the rivers of Bhutan for all time to come. Their conservation efforts are known to existed time immemorial through as depicted in the eight lucky signs of Bhutan. However, their importance and biology has been known recently. Two iconic flagship native species having such cultural and historical importance are:

i. Chocolate Mahaseer, *Accrossochelius hexagonolepis*
ii. Golden Mahaseer, *Tor putitora*
The contribution of non-native coldwater species can not be ignored as they were introduced into Bhutan several decades ago as part of Tshethar (Religious merciful release) and subsequently established into natural water bodies of the western and central Bhutan. Brown trout, *Salmo trutta* is believed to be introduced sometimes in 1930s into Haachu rivers for the purpose of Tshethar. For enhancing domestic fish production and reducing import, Rainbow trout, *Oncorhynchus mykiss* was introduced at Haa district for the hatchery production and subsequent supply to the enthusiast farmers. Now, it is seen that both the cold-water species are settled in the areas where they were introduced legally or through merciful release.

**Prospects of commercially important finfish aquaculture**

Bhutan has lots of religious stigma when anything comes to meat production and consumption. Every year Bhutan imports tons of meat and meat products from India and other neighboring countries, and the imports are in increasing trends. Bhutan imported fish alone worth of Nu. 350 million in year 2012 (Department of Livestock, 2012). The details of fish produced domestically and subsequent imports are presented in Table 1.

*Prospect of Golden Mahaseer (Tor putitora) as commercially important finfish for aquaculture*

Golden Mahaseer (*Tor putitora*) is widely distributed in the rivers of Bhutan. They are found in Amochu in Western region, Punatshangchu/ Sunkosh in West-central/ west-southern region, rivers of Sarpang region, Mangdechhu of Trongsa/ Zhemgang/ Manas region, Chamkharchhu of southern Bumthang region, and drainage basins of Drangmechu and rivers of Nyeramachu in the south-eastern regions of Bhutan. Golden Mahaseer is known by various names across Bhutan. Typically called Sernya (Golden Fish), Golden Mahaseer is depicted in eight lucky signs from time immemorial showing historical and cultural significance of fish. Today, Golden Mahaseer are seen as paintings on walls, windows of Bhutanese typical traditional houses as well as on Thangkas, altar and traditional flags showing in depth integrity of fish in Bhutanese social, culture and religious affairs.

Population of this endangered species has already decline by 50% and it is believed that if the trends continuous, population may decline by 80% in the near future (Internatural Union for Conservation of Nature and Natural Resources (IUCN) (2018). Like any other countries, in Bhutan, population of Golden Mahaseer is affected by anthropogenic activities such as hydro-power dam construction, river diversion, sand/ stone mining from rivers, in-
human or destructive fishing, fishing during spawning seasons and natural
disaster such as flash floods. Due to above demanding risks, National
Research and Development Centre for Aquaculture (NR&DCA), Gelephu
under the Department of Livestock (DoL) initiate propagation of this
pristine yet iconic species since 2012. With limited technical know-how,
human resources and other scarce resources, NR&DCA made historical
breakthrough in artificial propagation of endangered Golden Mahaseer in
year 2013. Till date, NR&DCA has released over 5000 numbers of viable
fingerlings into rivers of Sarpang region and over 2000 numbers into
Mangdechu river.

Though Golden Mahaseer has not gained momentum into commercial
culture, due to its iconic nature, it can have huge value in future to boost
recreational fisheries in Bhutan. Road-maps are in pipeline and soon we
hope to set up several recreational fisheries along Mangdechu,
Punatshangchu and other several rivers attracting national and international
tourist in and around the world. Also, it has great scope for commercial
aquaculure practices keeping in minds its huge growth size and demand for
its flesh.

Prospect of Chocolate Mahaseer (Tor putitora) as commercially important
finfish for aquaculture

Second to Golden Mahaseer, Chocolate Mahaseer has wide range of
distribution in the rivers of Bhutan. Due to its abundance and high demand
for its taste; Chocolate Mahaseer can definitely have high market demand in
near future. However, research to breed Chocolate Mahaseer artificially is in
infancy and several quality researches are required to breed Chocolate
Mahaseer in captivity to produce seeds for commercial farming. Currently,
NR&DCA, Gelephu is collecting the viable breeders of this species from
rivers of Sarpang region for artificial propagation. Still it is not clear that
these two Mahaseer species will be allowed for husbandry purpose since
both are protective speices meant for conservation.

Prospect of six major carps as commercially important finfish for
aquaculture

Aquaculture in Bhutan began in 1984 with a small carp seed production
unit. Till then, six cultivable species of carps have been main stay of
aquaculture industry in Bhutan. Dominated by three species of Indian Major
Carps, two species of Chinese Major Carps and one Common carp;
aquaculture industry is carp stagnant with small scale venture taking place
till date. Though domestic production was surplus in early 1990s no records
are available to authenticate the production status. Surplus production didn’t last long as it went into slump during late 1990s due to Southern uprising which again gained small momentum from year 2007 till date. Today Bhutan produces over 200 t of fish, however, import from India and other neighboring countries exceeds over 2000 t leaving behind huge scope and potential for producing fish domestically.

**Present hatchery production, seed rearing and aquaculture practices and production of commercially important fin fishes**

*Golden Mahaseer (Tor putitora) hatchery production and seed rearing*

Breakthrough in artificial propagation of Golden Mahaseer at NR&DCA, Gelephu was achieved in year 2013. The fish breeds twice a year during February-April and October-December. Brood-stock are being collected from different rivers of Sarpang region from year 1995 till date in the form of fingerlings, juveniles and few as adults. Now, NR&DCA, Gelephu has over 300 numbers of viable brood-stock of which about 50% population are female. All over the world, much success has not achieved in artificial propagation of Golden Mahaseer. At NR&DCA in breeding seasons ripped females and males are taken out of pond and stripped artificially. After stripping the eggs males are gently stripped for milts and fertilization is done with gently mixing of milts with eggs with the help of smooth feather. After washing away of excess milts, the fertilized eggs are incubated inside perforated trays with required aeration inside glass aquariums. Care is taken to avoid direct sunlight towards incubated eggs. Depending on water temperature hatching take place in three to five days. No feeding is done till ten to twelve days of post hatching, and there after meshed boiled egg is given in the form of slurry for two weeks. Slowly hatchlings are weaned over to soya bean juice and subsequently to crumbled fry to fingerling feed. Over eight months rearing the fish attain the size of about 14 g, and at this size they are ranched into the depleted water bodies in nearby rivers.

*Chocolate Mahaseer hatchery production and seed rearing*

Though Chocolate Mahaseer is abundant in the rivers of Bhutan, due to anthropogenic developmental activities their natural population is being threatened. At present, Chocolate Mahaseer is given less importance as compared to Golden Mahaseer and conservationist doesn’t necessarily object excessive capture of this species. Hence, in long run, there is chance that the of species become endangered or extinct. Taking consideration of above foreseen threats, NR&DCA, Gelephu collected over 500 numbers of
Chocolate Mahaseer fingerlings and juveniles from various rivers of Sarpang region for brood stock development. No hatchery seed production technology of this species exists till date in Bhutan.

**Carp hatchery production, seed rearing and aquaculture practices**

Method and technologies followed in carp hatchery production at NR&DCA, Gelephu is as same as elsewhere in India, Nepal and other countries having similar topographical and climatic features. During 1984 and early 2000s artificial propagation of Indian Major Carps and Chinese Major Carps were carried out in fixed cemented Chinese circular carp hatcheries. However, with availability of resources, fixed sets of infrastructures are now replaced with portable incubators with only different in spawning and egg collection technologies from the neighboring countries.

During breeding seasons, brood fish are collected from breeder’s ponds with the help of seine nets. They are conditioned for few hours before administering of artificial gonadotropin releasing hormone Ovatide. Successful spawning of ova takes places inside spawning happa instead inside circular spawning tanks of Chinese circular hatchery. Ova collection starts early morning with quantification after which incubation is done inside portable circular incubators. After successful hatching, hatchlings remain inside hatchery unit over a week and then subsequently get transferred to outdoor earthen nursery ponds. Feeding of hatchlings begins at fourth day with egg slurry, slowly weaning towards fry and fingerling feeds. After rearing over three months, they attain size of ordinary of about 1 gram to be distributed to farmers those who wish to acquire for table fish purpose.

**Issues and challenges**

**Environmental issues**

Total area under aquaculture production in the country is less than 100 acres mostly in backyard level of production. Few farmers provide commercial fish feeds occasionally with most households either go for locally available feeds or left without feeding for most of the time. Due to which aquaculture production in the country never had good increasing trends. Unavailable trends of using commercial feeds, chemical fertilizers and other chemical inputs have led to having no much environmental impact of aquaculture industry in Bhutan. Also, no concrete scientific
studies have been conducted till date to assess environmental issue likely to arise from aquaculture venture.

**Social issues**

There are no specific social issues but it’s one of the biggest hindrances to the growth of aquaculture sector in Bhutan, i.e. religious stigma or religious sentiments of local Bhutanese people. Killing of any live animal is considered to be sinful action against the belief of Buddhism. Because of this very belief, rearing of fish or any livestock commodities is challenging task since farmers voluntarily don’t want to rear but most of them consume on daily dinning routine. Also, religious stigma plays major roles in leaving aquaculture farms defunct with farmers leaving aquaculture ventures every year. Continued efforts are in place, sensitizing advantages of taking up aquaculture ventures in rural populace of Bhutan. Fund subsidy packages for aquaculture farm construction, free hands on training with daily applicable allowances, subsidized supply of live fish inputs and free technical backstopping are some of strategies and measures taken by government of Bhutan to attract people towards aquaculture industry.

**Planning and management issues**

Efficient planning and management of system is key towards development of any commercial ventures. Aquaculture like any other commodities required proper and efficient planning which is being executed by National Research and Development Centre for Aquaculture (NR&DCA), Gelephu under the support and guidance of Department of Livestock (DoL) of Ministry of Agriculture and Forests (MoAF), Royal Government of Bhutan. The planning and coordination are focused only towards the development of particular commodity centre, the then called NR&DCA, Gelephu for conduction of proper research and production of quality live fingerlings supply. Fish farmers being under purview of Dzongkhag livestock sector, all activities related to aquaculture planning, management, farm construction and management of aquaculture systems are being looked after and facilitated by Dzongkhags as well as Regional Livestock Development Centers. Only critical technical back-stopping, which Dzongkhags and Regional Livestock Development Centers feels lagging behind but it has been executed by NR&DCA, Gelephu in close consultation with above sectors.
Issues related to export of aquaculture products

Bhutan imports aquaculture products in excess of 2000 t whereas domestic productions merely exceed 222 t. Hence, Bhutan does not export any aquaculture products at the moment.

Institutional setup and stake holders involvement

- The aquaculture sector development in Bhutan is under the direct purview of Department of Livestock of Ministry of Agriculture and Forests
- Input supply and research by NR&DCA, Gelephu
- Aquaculture fund support, aquaculture farm constructions and technical backstopping by Dzongkhag livestock sector and Regional Livestock Development Centre’s under the same department
- Only critical technical backstopping by NR&DCA, Gelephu
- Marketing of aqua-commodities by RLDC’s and Department of Agricultural marketing

Recommendations

Capacity building

Lone aquaculture institution lacks human resource capacity in quality production of hatchery technologies such as:
- Breeder management
- Hatchery management
- Fry and nursing management
- Laboratory disease diagnostics and health management
- Feeding and Nutritional management in fishes

Short training or long term training funds for undergoing Diploma, certificates level, undergraduate/ master degree is highly recommended.

Policy development

- Policy towards enhancing the technical know-how in advancement of aquaculture technologies and quality research should be framed
- Policy towards commercializing aquaculture as means of nutrition security and rural livelihood should be framed
- Policy towards collaborating with advanced aquacultural countries should be taken up
• SAC should facilitate in overall development of aquaculture in the region particular in Bhutan

**Livelihood**

• More fund should be available towards development of aqua-farm and commercialization of existing farms for improving livelihood
• SAC may keep provision for fund support towards training of technical staffs/ fund for construction of aqua-farms in SAARC region

**Information**

• People of rural as well as urban should be kept informed on the prospect of taking up aqua-farming
• More funds should be made available for information dissemination to rural populace
• SAC should facilitate in sharing information on new/ advanced technologies in aquaculture

**Conclusion**

Bhutan has huge potential for development of fish production as stated with meager domestic production and substantial import from India and other neighboring countries. The production could be either warm-water as well as cold-water fisheries across the country. The need for introduction of other commercially viable species are of no concern since existing six species of major carps and two species of trout are in initial stage of backyard production. Given adequate fund support and social commitments, fish self-sufficiency in the country can be easily met from existing species in long run.

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Chapter 7

Aquaculture of Commercially Important Finfishes in Pakistan

Rehana Kausar
Pakistan Agricultural Research Council, Islamabad, Pakistan
rehanatiwana@gmail.com

Aquaculture Scenario

Aquaculture is a rather recent activity in Pakistan and is still in its infancy; nevertheless there is immense potential for development of the sector. Despite its vast fresh, brackish and marine water resources only carp culture is practiced in inland waters and only on a limited scale, carp are cultured in earthen ponds, using mostly extensive farming practices with very little inputs. In Pakistan, the fish fauna is rich but only seven warm water species and two cold water species are cultivated on a commercial scale.

The fisheries sector as a whole contributes to about 1% to the country’s GDP and provides jobs for about 1% of the country’s labor force. Freshwater carp farming is the major aquaculture activity in three of the country’s four provinces (Punjab, Sindh and KPK). The northern mountains of Pakistan have good potential for trout culture but production in these colder regions is still very small. Pakistan has not yet begun any coastal aquaculture although there is good potential all along 1,100 km coastline.

According to the latest estimates, the total area covered by fish ponds across all provinces is about 60,470 ha, with Sindh 49,170 ha, Punjab 10,500 ha, KPK 560 ha and the other provinces Balochistan, Azad Jammu Kashmir (AJK) and Northern Area (NA) 240 ha. About 13,000 fish farms have so far been established across Pakistan, the size of these farms varies considerably, however, the average farm size ranges form 5-10 ha.

Pakistan has substantial areas of inland waters as a result of its location as the drainage basin for the Himalayas. The region between 33°N and 20°N consists of a network of rivers, canals, reservoirs, lakes, waterlogged areas and village ponds, etc. with a total area of about 8.6 million ha. Of this total, some 30,000 ha correspond to the area utilized for cold-water trout production and other commercially important sport fishes such as mahseer (Tor tor) and snow trout (Schizothorax richardsonii ).
About 1,10,000 ha comprise the warm water natural lakes found in Pakistan of which the majority (1,01,000 ha) are found in Sindh Province, which has a mix of both freshwater and saline lakes. In some of these saline lakes, the salinity levels are higher than sea water thereby limiting their potential for fisheries production.

In Sindh Province, the majority of the farms are located in Thatta, Badin and Dadu, the three districts through which the River Indus passes. Badin and Thatta have water logged floodplain areas which are suitable for fish farming. In Punjab Province, farms are located mostly in irrigated areas or where there is abundant rain and the soil is alluvial. As a result, Sheikhupura, Gujranwala and Attock districts have larger number of farms and constitute around three quarters of the total number of farms in Punjab.

The KPK has comparatively fewer farms, because of the cold climate in the mountainous areas. Trout farms are located in Chitral, Swat, Dir, Malakand, Manshehra, Federally Administered Tribal Area (FATA) and other parts of NA. Carp culture is practiced in Dera Ismail Khan, Kohat, Mardan, Swabi and the Abbotabad districts of KPK.

While these resources possess great development potential to help meet the increasing demand for protein from the population, fish farming has never been a major economic activity neither have freshwater fish ever been a major food source for the inland population. The per capita consumption of fish products is currently around 1.9 kg which is amongst the lowest in the world.

No direct data on the number of fish farmers employed in this sector is available as fish farming in most parts of the country is carried out as an integral part of crop farming. According to a best estimate, about 50,000 people are either directly or indirectly employed in the sector.

**Cultured species**

In the past, most fish farmers stocked their ponds only with indigenous species such as catla (*Catla catla*), rohu (*Labeo rohi ta*), mrigal (*Cirrhinus mrigala*) and common carp (*Cyprinus carpio*). More recently, two fast growing species, the grass carp (*Ctenopharyngodon idellus*) and silver carp (*Hypophthalmichthys molitrix*), have been introduced for culture under modern polyculture systems to increase the fish yield per unit area. These two species have good economic values; have gained a reputation and became popular amongst the producers as well as consumers. Two species of trout namely brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) are cultured in KPK and AJK.
Cold water fishes

Figure 1. Rainbow trout

Figure 2. Brown trout

Warm water fishes

Indigenous carps

Figure 3. *Cirrhinus mrigala* (Mori)

Figure 4. *Labeo rohita* (Rohu)

Figure 5. *Catla catla* (Thaila)

Exotic carps (Chinese carps)

Figure 6. *Aristichthys nobilis* (Bighead)

Figure 7. *Ctenopharyngodon idella* (Grass carp)

Figure 8. *Hypophthalmichthys molitrix* (Silver carp).

Figure 9. *Cyprinus carpio* (Common carp)
Aquaculture practices

The organization of the Provincial Fisheries Departments was very poor at the beginning of aquaculture activities during 1980s and to some extent is still in a similar position in Balochistan and KPK provinces. With the exception of a pilot shrimp farm in Sindh and one pilot trout culture facility in KPK, virtually all aquaculture in Pakistan consists of pond culture of various carp species. The quality of carp pond design and construction is highly variable, some commercial farms are well built and managed, however, many more technical and management assistance are needed.

Carps are cultured in earthen ponds utilizing extensive poly-culture farming systems with very little inputs; in some farms semi-intensive culture has also been adopted. A combination of five or six of the three indigenous species of major Indian carps as well as 3 exotic species of Chinese carps are cultivated in the ponds. On a typical farm in Pakistan, the ratio of the warm water species stocked on the farm is as follows: catla (10-20%), rohu (30-35%), mrigal (15-20%), grass carp (15-20 %) and silver carp (15-20%). The intensive culture of these species has not yet been adopted so far, the major impediment to this development being the non-availability of low cost feed and to some extent the non-availability of intensive fish farming technology. The productivity of carp farms shows marked differences across the provinces with Punjab having the highest per unit production followed by Sindh and KPK.

Cold water aquaculture provides a unique opportunity in the mountainous areas of KPK, Balochistan, AJK and NA. Presently two species, brown trout and rainbow trout, are being produced and cultured successfully for use in sport fishing activities. The intensive rearing of trout is practiced in commercial raceways in Swat, Dir, Chitral and Hazara in KPK and in AJK and NA.

Future prospects

Pakistan has launched its first National Fisheries Policy which aims to increase exports of fish and shrimp to US$1 billion a year in six years time, up from about $200 million annually at present. Supported by a 2 billion rupees (US$33.4 million) budget to increase fish and shrimp output, the government programmed is intended to boost fisheries exports through a public-private partnership based on sustainable production growth of marine and inland fisheries.
Announcing the new initiative in December, the government told Pakistan’s fishing community that the new National Fisheries Policy could result in increased fishery production of about 53,000 metric tons (t) per year and higher seafood exports. The key to increasing fishery exports will be the achievement of a substantial reduction in the waste catch which, along with over-fishing, has held back fisheries development in recent years.

Many different organizations have planned to set up research projects covering both marine and inland fisheries as well as allied aquaculture. Emphasis on research surveys as well as research and development will make the industry projects grow at pace.

With concerted efforts along with proper incentives, the fisheries production is likely to increase, leading to its greater role in the national economy. Main focus of the scientists is to establish hatcheries to produce local quality seed to provide it at cheaper rates to the farmers. To increase the fish production there is dire need to establish fish feed mills to produce high quality feed at cheaper rates so this is one of the most focused aspects of this sector. Scientists are eager to introduce exotic high value fishes with its complete technology package. Many of the organizations are trying to establish fish processing units to supply the fresh quality stored fish which can be a good foreign earning.

**Hatchery production**

The main sources of fish seed are government and private hatcheries/nurseries of warm water fishes (Indian Major carps and Chinese carps) and cold water (trout) in four provinces of Pakistan. Freshwater carp farming which is by far the mainstay of aquaculture activity in the country is practiced widely in the two provinces of Punjab and Sindh and to a lesser extent in the province of KPK. In Punjab, 74 fish hatcheries are operated by the private sector while 14 hatcheries and nurseries are operated by the public sector. There are 5 hatcheries in Sindh, located at Chilya (Thatta), Mirpur Sacro and Sukkar. In Balochistan, there are only a couple of hatcheries; 8 warm water fish hatcheries and about 30 trout farms cum hatcheries are operating in the KPK. The hatcheries can further be classified on the basis of the types of cultured fish i.e. carp hatcheries, trout hatcheries and Mahaseer hatcheries.
Table 1. Fish hatcheries in Pakistan

<table>
<thead>
<tr>
<th>Types</th>
<th>Punjab</th>
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<td>1</td>
<td>-</td>
<td>5</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Mahaseer hatcheries</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2. Yearly carp seed production by public and private sectors

<table>
<thead>
<tr>
<th>Provinces</th>
<th>Government sector (million)</th>
<th>Private sector (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punjab</td>
<td>5.00</td>
<td>2.20</td>
</tr>
<tr>
<td>Sindh</td>
<td>1.90</td>
<td>1.10</td>
</tr>
<tr>
<td>Khyber Pakhtoon Khawa (KPK)</td>
<td>2.00</td>
<td>1.15</td>
</tr>
<tr>
<td>Balouchistan</td>
<td>0.9</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 1. Total aquaculture production of the Islamic Republic of Pakistan (t)

Source: FAO FishStat
Institutional framework

In Pakistan, aquaculture is a provincial responsibility, the Provincial Departments of Fisheries (DOF) in Punjab, KPK and Sindh are working actively towards the conservation and management of inland waters and the development of aquaculture in their respective provinces. In Balochistan, the DOF is involved mainly in marine fisheries but also has a component responsible for inland fisheries. The fisheries departments in the FATA, NA and AJK are relatively small and mainly aimed at the management of the trout fisheries. At the central level fisheries is the responsibility of the office of the Fisheries Development Commissioner (FDC), working under the Ministry of Food, Agriculture and Livestock (MINFAL). The office of the FDC is responsible for policy, planning and coordination with provincial fisheries departments and other national and international agencies. The Pakistan Agricultural Research Council (PARC) is the country's largest research organization and is responsible to MINFAL. Some universities in the country are also involved in basic fisheries research.

Freshwater fish culture in earthen ponds, both small and large reservoirs as well as community ponds was initiated in late 1960s by the provincial fisheries departments. Inland fish farming is under the control of the provincial governments, who supply seed, operate hatcheries, provide extension services, collect primary data and promote fisheries through extension manuals, brochures and by arranging seminars, etc. Existing
farming methods have not developed. However, as a result of a steady stream of newcomers to the sector, there is a slow but steady improvement in technology over time.

The Marine Fisheries Department (MFD) Karachi, an attached department of MINFAL, is responsible for the implementation of Deep Sea Fishing Policy and the regulation of exports of fish and fishery products.

The Water and Power Development Authority (WAPDA) working under the Ministry of Water and Power also has a fisheries department responsible for the regulation and auction of fisheries rights in the large reservoirs found in Pakistan. There is a fisheries research unit at the National Agricultural Research Center (NARC) of PARC, the country’s biggest research organizations established under the MINFAL. Some universities in the country are also involved in basic fisheries research.

The DOFs provide technical guidance, juveniles at subsidized rates to farmers as well as other extension services which have resulted in the establishment of a number of trout hatcheries/farms under private ownership. The government has also successfully transferred the technology gained by the Provincial Fisheries Departments to the private sector and as a result the number of farms is increasing.

Several universities and few organizations engaged in academic aquaculture research include are Pakistan Agricultural Research Council, Fisheries Research Institute, Manawa, Lahore, Punjab Fisheries Department, Trout Multiplication Research Center, Gilgit, University of Agriculture, Faisalabad, University of Veterinary and Animal Sciences, Lahore, University of Sindh, Jamshoro, Center of Excellence of Marine Biology, University of Karachi, Quaid-e-Azam University, Islamabad, Bahaudin Zakaraya University, Multan, University of Peshawar, Peshawar, University of Punjab, Lahore, Government College University, Lahore and (Marine) National Institute of Oceanography, Pakistan and Center of Excellence for the Marine Biology.

**Issues and challenges**

Despite several attempts by both the private and public sectors, aquaculture in the coastal areas of Pakistan has not yet been successful despite good potential. In almost all maritime countries, marine aquaculture has proliferated and became a major source of raw material for the export of seafood commodities. In the absence of a major aquaculture sector in Pakistan it has not been possible to compete with nations which have this
alternative and dependable source of raw material for export. Numerous factors restrain the aquaculture development such as:

**Environmental issues**

The biodiversity of natural water bodies and coastal areas has been seriously affected as a result of overfishing, pollution and environmental degradation. There is a need therefore to develop the aquaculture sector in a sustainable and responsible manner.

**Social issues**

Lack of coordination among institutions including Government, Non-governmental organizations, research institutes and universities and less interest of private sector.

**Planning and management issues**

Improper fishery policy and guidelines for the developing aquaculture. Shortage of national and international research projects as well as experts, especially in the areas of production system, fish nutrition, fish diseases and fish genetics. Limited budget for basic research and development projects is funded by the government. As there is no training is given to scientists, so insufficient scientific awareness to design aquaculture research and development projects results in developing new projects. Lack of technical services to fish farmers such as training packages and materials including with inadequate capacity is one of the basic issues in fish culture. Highest per unit cost due to improper management of production units. Poor assess to market and extension services. Expensive commercially produced seed and lack of quality fish seed.

**Recommendations**

Pakistan has a great potential of aquaculture for economic development that offers numerous opportunities including livelihood to local communities, contribution in food production, training and management staff, conservators, researchers, ecologist and business and other jobs through offering different aquaculture system such as integrated aquaculture, cage culture, bait culture, ornamental fish culture, export and import of fisheries product, integrated aquaculture, intensive aquaculture and culture-based fisheries.

Significance of Aquaculture Development In order to meet challenges, associated with national nutrition and food security, the trend to
Aquaculture is growing very fast. In this regard, following area need utmost attention for promotion of aquaculture.

**Aquaculture production**

There is a bottomless market demand for fish, especially major carps, in Pakistan. Mostly, fish is imported from Burma, Iran and China. Such circumstances forces to articulate appropriate aquaculture technology which will enhance fish production and productivity. Hence, cage culture should be promoted for commercial and out-grower scheme.

**Institutional cooperation**

There are appropriate fisheries institutions, from provincial to federal level, but due to lack of coordination the aquaculture policies are not implemented properly. Therefore, it is essential to collaborate and support government as well as private sector to ensure the aquaculture development.

**Evaluation and Monitoring**

Most of the statistical data reported by the institutes are often contradictory. Therefore, comprehensive information gathering tool should be developed to generate the baseline data on aquaculture. Hence, functional monitoring and evaluation domain must be developed.

**Proper policy and legal framework**

Sound policies are considered to be the base line for development of any sector. Government should make a proper policy to attract the business man for profitable aquaculture. Although government already has aquaculture strategic plan that need to be implemented for best aquaculture management practices by extending collaboration with the stakeholders. Pakistan is enriched with numerous aquaculture potential. Declining capture fisheries emphasizes to take serious efforts to revitalize the aquaculture sector.

The present article highlights an overview of the fisheries sector in Pakistan as well as its challenges and opportunities. Keeping in view the sustainability and farmers need we have to change the routine direction of aquaculture towards the comprehensive research in development approaches. The performance of fisheries sector is crucial from the perspective of nutrition security and national macroeconomic. In further, to articulate relevant aquaculture technologies meeting the nutritional, economical and food security needs, researchers and extension agents will
be required. Therefore, a more efficient and sustainable management of the aquatic resources is proposed that will contribute greatly to health and economy of the country. The quality feed and seed are the major critical input in aquaculture. Therefore, it is urgent need for aquaculture development to formulate the cost-effective fish feed and quality fish seed targeting especially the resource poor fish farmers. Along with these efforts, the community-based aquaculture projects must be encouraged and supported in a sustainable manner. In addition, the Inland Fisheries and Marine Fisheries Department would be required to expend considerable resources on on-farm research by using indigenous fish species and recommend species which would adapt on farm feed resources.

References


http://www.pakistanfishing.com/fishing-info/fishing-industry-in-pakistan
Chapter 8

National Aquaculture Policy of Sri Lanka

P. Nimal Chandratne
National Aquaculture Development Authority of Sri Lanka
dg.naqda@gmail.com

Introduction

The World Food and Agriculture Organization (FAO) predicts that the world’s population will reach over 9 billion within 2050, which is approximately 34% higher than today. Nearly all of this population increase is expected to occur in developing countries. Urbanization will also continue at an accelerated pace, and about 70% of the world’s population will become urban over next 3 decades (compared to 49% today). In addition, income levels in 2050 will be many multiples of what they are now. Hence, the biggest challenge in the future will be to find ways and means to provide food and gainful employment for this increasing population.

Compared to other industries, aquaculture has proven to be an efficient catalyst for production of seafood world-wide. Moreover, aquaculture has emerged as a major mode of food production required to maintain the current per capita consumption, which since 1984 shows an average annual growth rate of 11%. Thus, aquaculture is expected to increase rapidly both in volumes and species diversity, and thereby become a most important source of food and protein supply in the future.

Sri Lanka has a territorial sea of 21,500 km² and an Exclusive Economic Zone (EEZ) of 517,000 km². The country has a narrow continental shelf with an average width of 22 km. Its extent is 30,000 km² which is 5.8% of the country’s ocean area. The last survey of the coastal waters done in 1979-80 (Nansen Survey) indicated a possible annual yield of 250,000 tons of fish from the coastal inshore area, and 90,000 – 150,000 tons from deeper parts of EEZ. The 2018 Nansen Survey indicates that the production potential from the sea area off the western coast has slightly declined, while that from the sea off the eastern coast is stable. Sri Lanka also has extensive freshwater and brackish water resources that sustain viable capture fishing activities. These comprise around 260,000 ha of large irrigation reservoirs, 70,850 ha of medium sized irrigation reservoirs, 17,004 ha of minor irrigation reservoirs, 39,271 ha of seasonal village tanks (100,000 Nos), 41,049 of flood lakes, 8,097 of upland reservoirs and estate tanks and 22,670 ha of Mahaweli river basin.
reservoirs. Opportunities also exist for brackish water aquaculture notably in Puttalam, Batticaloa, and Mullaitivu districts. Coastal aquaculture is now practiced only in Puttalam and Batticaloa districts.

Sri Lanka is now in the process of embarking on a very ambitious aquaculture development plan, targeting doubling of aquaculture production to 95,000 metric tons. This goal is to be met through sustainable aquaculture development, addressing technology transfer, training programmes, food safety and quality, and environmental integrity.

**Sri Lankan aquaculture – history**

Freshwater fish culture in seasonal village tanks was initiated in 1979 by the Inland Fisheries Division of the Ministry of Fisheries with 23 tanks in the country’s dry zone and from 1979 onwards the polyculture of fish using tilapia and carp has been carried out. In the early 1980s a number of small-scale entrepreneurs and a few multinational companies responding to the incentives offered by the government, including duty free imports of inputs, embarked on the culture of giant tiger prawn (*Penaeus monodon*) in coastal ponds. In the late 1990s the commercial growing of the Indo-Pacific swamp crab (*Scylla serrata*) in plasticized wire mesh cages began in coastal lagoons.

In contrast, the ornamental fish industry in Sri Lanka has a long history and was started with household based small-scale outlets in cities. In the early 1930s, there were several small-scale exporters, breeders and hobbyists in Sri Lanka; a commercial aquarium was started in 1952 in Colombo. This industry was commercialized by a few entrepreneurs about 50 years ago and it has now developed into a thriving industry affording profits and employment for many. Ornamental fish culture is carried out mainly in cement tanks.

Sri Lanka is more or less designed for development of coastal aquaculture with a total coastline of approximately 1,700 km. The total extent of lagoons and estuaries has been estimated to be 121,000 ha. Adjoining these estuaries and lagoons are extensive areas of low-lying delta lands estimated at 70,000 ha.

Industrial aquaculture in Sri Lanka started in the early 1980’s by a few large multinational companies and a few medium scale entrepreneurs, who embarked on shrimp farming.

Inland fisheries and aquaculture have been developed in Sri Lanka for more than 75 years. Coastal aquaculture commenced in Sri Lanka in early 1980’s with the establishment of shrimp farms in the North-Western province.
Marine aquaculture started much later, around 2010. Sri Lanka possess a total of 1580 ha of lagoons and estuaries and 5200 sq km of man-made lakes. Bays, lagoons, reservoirs and certain lands located in coastal and reservoir areas make the resource base for development of aquaculture in Sri Lanka.

In 1990 the government decided to withdraw state support/patronage for inland fisheries and aquaculture ostensibly on religious grounds. This policy change disrupted the first growing fisheries and aquaculture sector. The Inland Fisheries Division of the Ministry of Fisheries was closed, some government seed production/demonstration centers were privatized and the reservoir stocking programme was discontinued. This resulted in a steady decline in the reservoir fisheries production, affecting the livelihood and food security of the people that depended on reservoir fisheries, and protein supply in the respective area. However, there was an unexpected beneficial side effect from this policy change, some of the staff laid off from the Inland Fisheries Division provided effective extension services to the people engaged in aquaculture. As a result, an organized private sector emerged with a keen interest in aquaculture. The policy change was reversed five years later with the change of the government and inland fisheries and aquaculture was again given state priority and support.

The primary policy making body for the sector is the Ministry of Fisheries and Aquatic Resources (MFAR) and the principal implementation arms of the Ministry are the Department of Fisheries for Marine Capture Fisheries, and the National Aquaculture Development Authority (NAQDA) for freshwater capture fisheries and aquaculture. There are other statutory bodies within the sector such as the National Aquatic Resources Agency (NARA) responsible for research, Ceylon Fisheries Corporation (CFC) for marketing, and (Ceylon Fishery Harbors Corporation (CFHC) for fishery harbor development and management. The National Institute of Fisheries and Nautical Engineering (NIFNE), which was responsible for training is recently transferred out of the Ministry.

The Fisheries Aquatic Resources Act No: 2 of 1996 is the principal legal instrument relating to the fisheries sector under which a number of regulations have been framed for the management of fisheries and aquaculture. The regulations are enforced by the fisheries inspectors in the marine capture fisheries sub-sector and the extension officers of NAQDA in the inland capture fisheries and aquaculture sub-sector.
Overview of the aquaculture policies in Sri Lanka

Overview of the past status

The overall National Fisheries and Aquaculture policies of Sri Lanka were contained in the policy of the former government (2005 and update version vision for the Future 2010). In the action path, the Fisheries and Aquatic Resources Sector is guided primarily by the strategies and actions enunciated in the Ten Year Development Policy Framework for 2007-2016. This was a comprehensive plan of action prepared under the aegis of the Fisheries Development component of the economic policy of the former government. Under this overall policy framework, the development objectives for the sector are laid as:

- Improvement of the nutritional status and food security of the people by increasing the national fish production;
- Minimizing of post-harvest losses and improving of quality and safety of fish products to acceptable standards;
- Increasing of employment opportunities in fisheries and related industries and improving the socio-economic status of the fisher community;
- Increasing of foreign exchange earnings from fish products;
- Conservation of the coastal and aquatic environment.

Overview of the current status

The Government of Sri Lanka with the technical assistant from the Government of Norway formulated the National Fisheries and Aquaculture Policy with the guidance from the Government’s Economic policy framework document V 2025. Accordingly, the Norwegian Ministry of Trade, Industries and Fisheries, in consultation with the Fisheries Ministry of Sri Lanka developed a project which will be funded by a grant from the Government of Norway. The objectives of the project are to assist the Sri Lankan Government to formulate a new fisheries and aquaculture policy to suit the current and emerging needs of the sector, develop manpower for management and facilitate investment in the sector. Two workshops were conducted under the Project in January 2017 with the participation of a team of Norwegian consultants to obtain a clear understanding of the sector, its past trends, current status, issues, confines and constraints and future development prospects to be used as a platform for policy formulation and to identify the limitations, confines and constraints imposed by external factors (other subjects and sectors) on the development of fisheries and
design mitigation measures. Officials involved in the development and management of fisheries and aquaculture both at the national and provincial level, scientists and experts, industry partners and fisher representatives were among the workshop participants. The workshops were concluded on 12 January 2018 with the participation of the Minister, State Minister, Provincial Ministers of Fisheries and Charge de Affairs of the Norwegian Embassy in Colombo.

The Sri Lankan private sector involvement in offshore fish farming has been limited due to the high cost of production and the high cost of commercial feed and as a solution that the Ministry of Primary Industries is also intervening timely by providing a series of financial and infrastructure incentives to promote fish farms.

**Objectives of development**

The Government envisages achieving the following objectives from implementation of the new Policy in the fisheries and Aquaculture sector.

- Sustainable management of resources using science-based information
- Compliance with regional and international obligations
- Increase of marine fisheries production
- Increase of aquaculture and inland fisheries production
- Minimizing of post-harvest losses and increased value addition
- Increasing of per capita consumption of fish
- Increasing of export earnings
- Improving of opportunities for leisure, employment and enterprises development
- Improving of socio-economic conditions of the fisher community

**Policies**

The policies developed under the present policy framework are being presented under five areas:

- Marine fisheries
- Aquaculture and inland fisheries
- Consumers and markets
- Blue economy
- Other areas
Policy on aquaculture and inland fisheries

The Government of Sri Lanka has identified the policies on development of Aquaculture and Inland Fisheries based on the following topics

Sustainable management of resources

The Government will:

- Apply ecosystem approach to management of fisheries in inland waters
- Ensure conservation of aquatic biodiversity in inland waters
- Regulate the length and engine capacity of fishing vessel fishing in lagoons and estuaries
- Not allow the use of motorized boats for fishing in reservoirs
- Apply temporal and spatial planning in development of aquaculture
- Allocate land and water resources for aquaculture projects only after environmental, socio-economic and cultural impact assessments
- Ensure that aquaculture projects are implemented in strict compliance with conditions of approval
- Strengthen the aquaculture- animal healthcare activates
- Promote the use of best management practices (BMPs) in aquaculture

Strengthening of governance

The Government will:

- Use management information systems for planning, development, management and reporting
- Strengthen the co-governance and co-management processes
- Develop human resources required for governance
- Utilize part of the earnings from fisheries in each inland water body for sustainable management of fisheries in the respective water body

Increasing of fish production

The Government will:

- Develop fisheries and aquaculture as appropriate in inland waters.
- Promote fishing for under-exploited and unexploited fish resources in inland waters.
- Expand and intensify aquaculture through environmentally friendly approaches.
• Promote the culture of indigenous species, and new exotic species in compliance with the Food and Agriculture Organization (FAO) Code of Practice for the Introduction of Aquatic Species.

• Genetically improve the performance of fish species used for aquaculture with the application of the precautionary principle.

**Generation of employment opportunities**

The Government will:

• Work for generation of more employment opportunities in the sector where possible

• Assist women in the fisher communities to set up micro-business enterprises with special attention to widows

• Provide training and capacity building programmes to assist women and marginalized groups to take up supplementary income generation activities

• Encourage communities to commence business activities including integrated sustainable tourism

• Motivate communities to commence aquaculture or culture-based fisheries as income activities in wetland areas associated with their villages

• Train school leavers in advanced technology related to fisheries, aquaculture and new marine industries targeting employment

• Train skippers and crew members for foreign employment

• Continue to implement the poverty alleviation programmes that provide sustainable livelihoods

**Environment, climate and natural disasters**

The Government will:

• Develop a strategy to address the environmental and climatic-change challenges and impacts of natural disasters

• Take possible precautions to prevent marine pollution given its direct adverse impacts on fish and other living marine aquatic resources

• Provide assistance to the communities affected by disasters to resettle and recommence livelihoods

• Formulate an inter-institutional network system of responsible authorities to address impacts of natural disasters
• Develop peoples’ resilience capacity to cope with climatic change impacts
• Improve the research work and institutional involvement to fill the information gaps and develop a database on climate change related issues

**Gender**

The Government will:
• Promote equal opportunities for women’s participation in the activities of the sector
• Make gender mainstreaming an integral part of small-scale fisheries development strategies
• Create conditions for both men and women to have equal access to resource and benefits
• Encourage both men and women to participate jointly in finding solutions to their problems

**Improvement of the socio – economic conditions of the fisher communities**

The Government will:
• Take measures to prevent alcoholism in fishing communities
• Ensure that adequate compensation is provided to fisher communities who will be affected by development activities in the respective areas
• Improve the social safety net and social security protection for the fishers and fish workers including women
• Respect the tenure rights of the traditional, migrant, subsistence and artisanal fishing communities to land, waters and fish resources
• Ensure safe, healthy and fair working conditions at sea, inland waters and on land
• Involve fishing communities in designing, planning and implementation of fisheries management measures
• Build the capacity of fishers and ensure their effective participation in fisheries management
• Promote investment in human resource development such as health, education, literacy and digital inclusion in fishing communities
• Progressively realize rights of the small-scale fishers and fish workers to an adequate standard of living in accordance with the national and international human right standards
Subsidies
The Government will:
- Use subsidies only as a tool in management of fisheries
- Wean away the fishers from the mentality of dependency on subsidies

Financing facilities
The Government will:
- encourage private financial institutions to develop financial instruments to ensure financial inclusion for fishers
- Encourage fisher communities to deal with bank and other formal credit institutions for their financial requirements

Private sector participation
The Government will:
- Promote the private sector participation in the sector
- Promote the establishment of public–private partnerships (PPPs) for investment in the sector

Human rights
The Government will:
- Ensure that no human rights are violated development and management of fisheries and aquaculture

Anti-corruption
The Government will:
- Work for prevention of corruption and economic fraud including fish-laundering in the fisheries and aquaculture sector

Fisher organization
The Government will:
- Recognize, empower and strengthen fisheries cooperatives in addressing issues in fisheries and fisher wellbeing and in representing fishing communities at decision making platforms
- Liaise with fisheries cooperatives in integrated coastal zone management

In order to expect the ensuring of sustainability of the fisheries and aquaculture industry the implementation of the above policy is expected
through effective governance and management mechanisms with the participation of all stakeholders through a participatory and holistic process. Such a process will ensure the achievement of both ecosystem health goals and human development goals. The outcome of the above goals will be a transformation of the fisheries and aquaculture industry to a knowledge-based, sustainable and modern industry that benefits all stakeholders.

References
Chapter 9

Productivity Improvement of Pond Fish Culture in Sri Lanka Through Cohort Bred GIFT Tilapia All Male Fingerlings

H.M.U.K.P.B. Herath
National Aquaculture Development Authority of Sri Lanka
herathup@yahoo.com

Introduction

Freshwater aquaculture is still in developing stage in Sri Lanka, contributing less than 10% of the total annual fish production, while capture based fisheries account for over 90%. The demand for freshwater fish is continuously increasing and current per capita fish consumption in the country is 17 kg. There are lots of opportunities of commercial fish farming in Sri Lanka. The freshwater fishes produced from the water bodies viz., reservoir are sold in the nearby villages and a very small portion is supplied for urban consumption. Therefore, the urban population have limited excess of freshwater fishes throughout the year. Tilapia is the most preferred freshwater fish all over the country and fetches higher price than that of carps. Normally, freshwater fishes are rarely available in supermarkets as there is no continuous supply of good quality fish. Most of the hotels and sound income group people prefer to buy processed fish (fillet, skinned fish), if available.

Gift tilapia has the highest growth performance among all tilapia varieties available in the country. For aquaculture tilapia seeds are easily available from the Aquaculture Development Centers (AQDC) of National Aquaculture Development Authority (NAQDA) of Sri Lanka. New commercial tilapia farms also produce all-male tilapia fingerlings through hormone treatment. All male tilapia fish seed production units are established by the private hatcheries with the technical support of NAQDA.

Sri Lanka is an island country with a land area of about 65,000 km² situated in the Indian Ocean. The country has an Exclusive Economic Zone (EEZ) of 517,000 km². There are five major brackish water lagoons and estuaries, which spread along the coastline of the country with the total water area of 160,000 ha. A total of 261,941 ha of freshwater bodies exist in the country, which includes over 157,892 ha perennial reservoirs, about 100,000 ha
seasonal reservoirs and about 4049 ha flood-plain lakes (Table 1). It has been estimated that the inland waters of the country have the potential to produce more than 275,000t of fish annually and the inland fish production including aquaculture has been increased with a present production of 88,010t (Table 2).

Fish is a major source of animal protein for developing countries like Sri Lanka. Currently fisheries sector produces over 523,000t of fish annually both from marine and inland fisheries (Table 3), where about 582,000 people are involved directly or indirectly in this sector. About 65% of the animal protein consumed in Sri Lanka is contributed by fish and the country produces 83% of its fish requirement at present, which is mainly coming from the marine capture fisheries. Freshwater fishery and aquaculture contribute about 17% to the country’s total fish production.

Table 1. Estimated surface area of water bodies of Sri Lanka

<table>
<thead>
<tr>
<th>Type of water bodies</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large reservoirs</td>
<td>70,850</td>
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<tr>
<td>Medium reservoirs</td>
<td>17,004</td>
</tr>
<tr>
<td>Minor reservoirs</td>
<td>39,271</td>
</tr>
<tr>
<td>Seasonal tanks</td>
<td>100,000</td>
</tr>
<tr>
<td>Flood lakes and villus</td>
<td>4,049</td>
</tr>
<tr>
<td>Upland reservoirs</td>
<td>8,097</td>
</tr>
<tr>
<td>Mahaweli reservoirs</td>
<td>22,670</td>
</tr>
<tr>
<td>Total</td>
<td>261,941</td>
</tr>
<tr>
<td>Brackish water resources</td>
<td>160,000</td>
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Table 2. Freshwater fisheries and aquaculture production (t)

<table>
<thead>
<tr>
<th>Year</th>
<th>Capture</th>
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<th>Shrimp farms</th>
<th>Total</th>
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<td>2012</td>
<td>58,680</td>
<td>6,960</td>
<td>3,310</td>
<td>68,950</td>
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<tr>
<td>2013</td>
<td>55,020</td>
<td>7,460</td>
<td>4,430</td>
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<td>2014</td>
<td>68,820</td>
<td>1,780</td>
<td>5,150</td>
<td>75,750</td>
</tr>
<tr>
<td>2015</td>
<td>57,060</td>
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<td>7,090</td>
<td>67,300</td>
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<td>2016</td>
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<td>9,792</td>
<td>6,028</td>
<td>73,925</td>
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<tr>
<td>2017</td>
<td>68,504</td>
<td>9,410</td>
<td>4,626</td>
<td>82,540</td>
</tr>
<tr>
<td>2018</td>
<td>71,014</td>
<td>8,815</td>
<td>8,181</td>
<td>88,010</td>
</tr>
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</table>
Table 3. Total Fish Production (t)

<table>
<thead>
<tr>
<th>Year</th>
<th>Marine fish catch</th>
<th>Total Marine</th>
<th>Inland and Aquaculture</th>
<th>Total fish production</th>
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<tbody>
<tr>
<td></td>
<td>Off-shore</td>
<td>Coastal</td>
<td>Off-shore</td>
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<tr>
<td>2010</td>
<td>129,840</td>
<td>202,420</td>
<td>332,260</td>
<td>52,410</td>
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<td>2011</td>
<td>162,920</td>
<td>222,335</td>
<td>385,270</td>
<td>59,560</td>
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<td>2012</td>
<td>159,680</td>
<td>257,540</td>
<td>417,220</td>
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<tr>
<td>2015</td>
<td>183,870</td>
<td>269,020</td>
<td>452,890</td>
<td>67,300</td>
</tr>
<tr>
<td>2016</td>
<td>182,830</td>
<td>274,160</td>
<td>456,990</td>
<td>73,930</td>
</tr>
<tr>
<td>2017</td>
<td>189,720</td>
<td>259,720</td>
<td>449,440</td>
<td>82,540</td>
</tr>
<tr>
<td>2018</td>
<td>190,350</td>
<td>245,020</td>
<td>435,370</td>
<td>88,010</td>
</tr>
</tbody>
</table>

Status of aquaculture

Sri Lanka has vast resources of inland waters, but it did not bear the tradition of food fish aquaculture. The commercial inland fishery developed in Sri Lanka only after the introduction of the exotic *Oreochromis mossambicus* into the freshwaters in 1951. The inland fish production is mainly confined to the irrigation reservoirs. The fishing is done by the fishermen by using gill nets and non-motorized crafts.

In order to popularize aquaculture, NAQDA with the financial support from the Ministry of Fisheries, started pond aquaculture development program in 2011. The ministry provides subsidy in the form of cash grants to meet the part of the cost of pond construction and fingerlings purchase along with the technical assistance. Also, fish culture in seasonal village tanks was initiated in 1979 by the Inland Fisheries Division of the Ministry of Fisheries, in a pilot scale. At present there are two major commercial aquaculture industries in Sri Lanka i.e. shrimp farming industry and ornamental fish farming industry.

Fresh water food fish and marine fish culture in the country is in developing stage. NAQDA under the Ministry of Fisheries and Aquatic Resources Development, play a major role in breeding the freshwater fish and prawn as well as marine fish to fulfill the seed requirements of the farmers. Aquaculture industries of the country have also emphasized on the species diversity to increase production. Several species were introduced in to the
water bodies and grow-out culture was started with different species combination (Table 4 & 5)

Table 4. Fish species which were introduced to Sri Lanka

<table>
<thead>
<tr>
<th>Species</th>
<th>Origin</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Oreochromis mossambicus</em></td>
<td>East Africa</td>
<td>1951</td>
</tr>
<tr>
<td><em>O. niloticus</em></td>
<td>East Africa</td>
<td>1956</td>
</tr>
<tr>
<td><em>Tilapia rendalli</em></td>
<td>East Africa</td>
<td>1969</td>
</tr>
<tr>
<td><em>Salmo trutta</em></td>
<td>Europe</td>
<td>1982, 1983</td>
</tr>
<tr>
<td><em>S. gairdneri</em></td>
<td>North America</td>
<td>1899, 1902</td>
</tr>
<tr>
<td><em>Cyprinus carpio</em></td>
<td>Europe, Singapore</td>
<td>1915, 1948</td>
</tr>
<tr>
<td><em>Osphronemus guramy</em></td>
<td>Indonesia</td>
<td>1927</td>
</tr>
<tr>
<td><em>Ctenopharyngodon idellus</em></td>
<td>China</td>
<td>1948, 1975</td>
</tr>
<tr>
<td><em>Hypopthalmicthys molitrix</em></td>
<td>China</td>
<td>1948, 1981</td>
</tr>
<tr>
<td><em>Catla catla</em></td>
<td>India</td>
<td>1942, 1982</td>
</tr>
<tr>
<td><em>Labeo rohita</em></td>
<td>India</td>
<td>1982</td>
</tr>
<tr>
<td><em>Aristichthys nobilis</em></td>
<td>China</td>
<td>1948</td>
</tr>
<tr>
<td><em>Cirrhinus mrigala</em></td>
<td>India</td>
<td>1981</td>
</tr>
<tr>
<td>Red tilapia</td>
<td>Thailand</td>
<td>1998</td>
</tr>
<tr>
<td>Gift tilapia</td>
<td>Thailand/ Malaysia</td>
<td>2000/2007/2015</td>
</tr>
<tr>
<td>Saline tilapia</td>
<td>Thailand</td>
<td>2016</td>
</tr>
<tr>
<td>Blue tilapia</td>
<td>China</td>
<td>2016</td>
</tr>
<tr>
<td>Species</td>
<td>Production (t)</td>
<td>Contribution(%)</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Tilapia</td>
<td>51806</td>
<td>59</td>
</tr>
<tr>
<td>Rohu</td>
<td>2933</td>
<td>3</td>
</tr>
<tr>
<td>Catla</td>
<td>6180</td>
<td>7</td>
</tr>
<tr>
<td>Common Carp</td>
<td>1255</td>
<td>1</td>
</tr>
<tr>
<td>Big Head Carp</td>
<td>8</td>
<td>0.01</td>
</tr>
<tr>
<td>Silver Carp</td>
<td>22</td>
<td>0.02</td>
</tr>
<tr>
<td>Mrigal</td>
<td>2323</td>
<td>3</td>
</tr>
<tr>
<td>Grass Carp</td>
<td>19</td>
<td>0.02</td>
</tr>
<tr>
<td>HiriKanaya</td>
<td>298</td>
<td>0.3</td>
</tr>
<tr>
<td>Lula</td>
<td>1644</td>
<td>2</td>
</tr>
<tr>
<td>Cultured Shrimps</td>
<td>8181</td>
<td>9</td>
</tr>
<tr>
<td>Fresh water prawns</td>
<td>1359</td>
<td>2</td>
</tr>
<tr>
<td>Milk fish and sea bass</td>
<td>514</td>
<td>1</td>
</tr>
<tr>
<td>Oyster and Crabs</td>
<td>185</td>
<td>0.2</td>
</tr>
<tr>
<td>Sea weed</td>
<td>322</td>
<td>0.4</td>
</tr>
<tr>
<td>Sea cucumber</td>
<td>196</td>
<td>0.2</td>
</tr>
<tr>
<td>Lobster</td>
<td>19</td>
<td>0.02</td>
</tr>
<tr>
<td>Other wild fish</td>
<td>10746</td>
<td>12</td>
</tr>
</tbody>
</table>

**Tilapia aquaculture in Sri Lanka**

Pond culture of tilapia is the most established freshwater aquaculture practice in Sri Lanka. Before 2011 tilapia pond fish culture practice was undertaken with mixed sex seeds of tilapia, which was not popular among the farmers due to negative impacts on growth. Some data on its culture by stocking mixed sex seed, conducted in Anuradhapura district is shown in table 6. Farm-made feeds with 25% protein was fed at 1-2% body weight daily. Pond fertilization was done by adding cow dung.
Table 6. Tilapia mixed sex culture practices in Anuradhapura district in 2011

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of mud ponds selected for stocking</td>
<td>06</td>
</tr>
<tr>
<td>Average size of a pond (m²)</td>
<td>1000</td>
</tr>
<tr>
<td>Stocking density of fingerlings/ m²</td>
<td>02</td>
</tr>
<tr>
<td>Stocking size of fingerlings (g)</td>
<td>02</td>
</tr>
<tr>
<td>Culture period (months)</td>
<td>07</td>
</tr>
<tr>
<td>Survival rate (%)</td>
<td>75</td>
</tr>
<tr>
<td>Average body weight at harvesting (g)</td>
<td>240</td>
</tr>
<tr>
<td>Average total harvest per pond (kg)</td>
<td>360</td>
</tr>
<tr>
<td>Income per pond (Rs.)</td>
<td>72,000</td>
</tr>
<tr>
<td>Total cost per cycle per pond (Rs.) (feed, fingerling, transport etc.)</td>
<td>48,000</td>
</tr>
<tr>
<td>Profit per pond per cycle (Rs.)</td>
<td>24,000</td>
</tr>
</tbody>
</table>

From 2011 several AQDC’s of NAQDA begin to produce all-male tilapia fish seeds using hormone treatment and distributed to farmers. NAQDA also carried genetic improvement programme for tilapia brooders. The first cohort breeding programme in tilapia was started in 2007, which continued up to tenth generation. This attempt ensured the sufficient genetic gain over each generation while minimizing the intensity of inbreeding. Different tilapia families needed for Cohort breeding programme were imported from World Fish Center –Malaysia during 2007 and also in 2015.

**Cohort (rotational breeding) breeding program**

4000 tilapia were introduced to Dambulla Aquaculture Development Center under National Aquaculture Development Authority of Sri Lanka on 19\(^{th}\) October 2015. The fry used were belonged to 40 families and each family was consisted of 100 fish. The family selection was done considering their superior growth performance. It is expected to minimize the inbreeding intensity while maintaining the better growth performance by conducting these cohorts breeding programme. Therefore, 40 families were divided into 8 cohorts and each cohort consisted of 5 families, according to the guideline of WorldFish Center. The fries imported from WorldFish center were grown in to brooders in separate ponds (400m²) and named as G-0 brood stock. G-0 breeding was conducted rotating males of adjacent tank without considering ratio of brooders (Figure 1). Males from pond 1 were shifted to mate with the females of pond 2, while males from pond 2 were used for the females of pond 3 and so on.
After mating, 5,000 to 10,000 fry were collected from each pond and were rear separately until they grow in to fingerlings. Then randomly collected 1600 fingerlings were grown in the respective ponds to get G-1 brood stock.

Apply the mating strategies in diagrams 2

Figure 1. Sketch of Tilapia cohort breeding at Dambulla

Figure 2. Layout of the tilapia breeding scheme
With the sexual maturity, best 200 males and 200 females were collected as parents of the second generation (G-1). Crossing ratio of G1 generation was 3(female): 1(male). Rotational mating scheme was conducted (Figure 2 and 3). The males from tank 1 mated with females of tank 3 while males of tank 2 mated with female of tank 4 and so on. Crossing programme was conducted using randomly collected 120 females and 40 males. Nursing and rearing was done in respective cement tanks (6m x 4m x 1m).

To get maximum outcome, all crossing schedules were conducted rotating males from cohort 01 to cohort 08. From 2015, G-3 was completed up to now and ready to cross for G-4. AQDC center at Dambulla provided 12500 brooders, 24100 preparatory brooders to NAQDA centers and private farms. Till date 21 million fingerlings and 28 million fry have been produced under this programme at Dambulla AQDC. Also, this centre has produced 0.6 million all male tilapia fry and 0.85 million all male tilapia fingerlings since 2016 and supplied to fish farmers.

**Pond fish culture with improved Gift Tilapia all-male fingerlings**

The 13 ponds in Gampaha district were stocked with improved 3rd generation tilapia fingerlings obtained from Dambulla AQDC in 2018. These fingerlings with an average size of 14.5g were transferred to final grow out ponds. The average size of the grow-out pond was 1000 m². Some important
parameters and data related to these tilapia grow out ponds are shown below.

Table 7. Tilapia production in the demonstration ponds in Gampaha district

<table>
<thead>
<tr>
<th>Items</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of fingerling to advanced fingerling rearing ponds</td>
<td>2</td>
</tr>
<tr>
<td>Size of rearing pond (m²)</td>
<td>1,000</td>
</tr>
<tr>
<td>Number of all-male fingerlings stocked in rearing ponds</td>
<td>80,000</td>
</tr>
<tr>
<td>Stocking density of fingerlings</td>
<td>40</td>
</tr>
<tr>
<td>Survival rate of advanced fingerlings (%)</td>
<td>80</td>
</tr>
<tr>
<td>Number of grow-out ponds</td>
<td>13</td>
</tr>
<tr>
<td>Size of a grow out pond (m²)</td>
<td>1,000</td>
</tr>
<tr>
<td>Stocking density of advanced fingerlings in grow-out ponds</td>
<td>4</td>
</tr>
<tr>
<td>Culture period in grow-out ponds (months)</td>
<td>4</td>
</tr>
<tr>
<td>Survival rate at final harvesting (%)</td>
<td>70</td>
</tr>
<tr>
<td>Average weight of fish at harvesting (g)</td>
<td>340</td>
</tr>
<tr>
<td>Total fish production from 13 ponds (kg)</td>
<td>12,376</td>
</tr>
<tr>
<td>Average fish production per pond (kg)</td>
<td>952</td>
</tr>
</tbody>
</table>

Table 8. Fish production cost and profit from each grow-out pond per culture cycle

<table>
<thead>
<tr>
<th>Items</th>
<th>Sri Lanka Rupee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input cost</td>
<td></td>
</tr>
<tr>
<td>Advanced fingerlings</td>
<td>20,000</td>
</tr>
<tr>
<td>Transport</td>
<td>2,000</td>
</tr>
<tr>
<td>Fish feed</td>
<td>100,000</td>
</tr>
<tr>
<td>Management and other</td>
<td>10,000</td>
</tr>
<tr>
<td>Total input cost</td>
<td>132,000</td>
</tr>
<tr>
<td>Income from fish sales per pond</td>
<td>285,600</td>
</tr>
<tr>
<td>Profit per pond per cycle</td>
<td>153,600</td>
</tr>
<tr>
<td>Profit per year (02 cycles per year)</td>
<td>307,200</td>
</tr>
</tbody>
</table>
Constraints

Some of the main constraints related to tilapia pond fish culture and possible overcome methodologies are listed below.

- **Higher fish feed cost**
  NAQDA has already developed several low cost feed formulas with locally available ingredients, which may take care of cost of production.

- **Higher power (electricity) cost**
  Incorporation of solar power unit is essential to minimize power cost.

- **Insufficient skilled work force**
  Training to the new learners is essential with the help of some skilled personal available in the country. The training may support the tilapia farming for higher magnitude production.

Conclusion

The farmers are getting higher incomes through pond fish culture with all-male fingerlings of improved GIFT strains from Aquaculture Development Centers of NAQDA. However, higher cost for fish feeds and energy are the two main issues to be address in order to popularize tilapia pond fish culture in Sri Lanka.

References


Introduction

Fisheries and aquaculture provide opportunities towards food- and nutrition security of the growing population and alleviating poverty. Aquatic resources play a significant role across the food chain, linking ecosystems, economic development and human well-being since the contribution of capture fisheries to global food fish supplies has leveled off.

In Sri Lanka, the contribution of the fisheries sector to the Gross Domestic Product (GDP) has been only 1.3 % for last few years. Fish and fishery products are the main preferred animal protein source and contributes around 70% to the total animal protein intake of the people. Still the per capita fish consumption has not yet reached 21.0 kg, the slandered set by the Medical Research Institute (MRI) for the food and nutritional security.

Sri Lanka with extensive aquatic resource is expected to achieve the nutritional and food security of the community. During 2017, there was no significant increase in fish production compared to the levels recorded in 2016. There was a very marginal increase in the total fish production by 0.1% to 0.53 million metric tons (MMT) in 2017. Marine fish production accounted for 84.6% of the total fish production in 2016. The reduction in marine fish production was the result of the decline in coastal fish production.

Resources for mariculture and coastal aquaculture development in Sri Lanka

Mariculture

Mariculture involves culture of aquatic organisms both plants and animals in a confined environment to achieve sustainable development goals. At present, floating cages, net enclosures, earthen ponds and constant water circulation systems are in use for fish culture in the country. Mussel, oysters, sea cucumber and seaweed culture are at their initial stages in Sri Lanka. Floating cages used for fish culture are seen in the open sea or large
sheltered bays. Net enclosures barricading large areas in sheltered bays, are being tried on a commercial scale in some countries. But these require considerable capital outlay and frequent replacement. Earthen ponds constructed to impound spring tide water are the most suitable structure for mariculture. Constant water circulation units are popular in some developed countries. This system requires heavy capital outlay and also high recurrent costs.

Maritime jurisdiction of Sri Lanka

The Exclusive Economic Zone (EEZ) extends 200 nautical miles from the coast line and covers an area of over 2,30,000 sq. km and the continental shelf covers a total area of about 26,000 sq. km. The territorial limit of the island extends to 19.2 km offshore (Fig. 1).

![Figure 1. Maritime boundaries of Sri Lanka](image)

The lengths of the coastline and lagoon shoreline of Sri Lanka are 1,338 and 2,791 km, respectively. Table-1 indicates the length of coastline, lagoon area, perimeter and number of lagoons on each coastal sector of Sri Lanka.
Table 1. Length of coastline, lagoon area, perimeter and number of lagoons on each coastal sector

<table>
<thead>
<tr>
<th>Coast</th>
<th>Coastline (km)</th>
<th>Lagoon area (km²)</th>
<th>Lagoon perimeter (km)</th>
<th>Number of lagoons</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>403</td>
<td>804</td>
<td>1,221</td>
<td>17</td>
</tr>
<tr>
<td>Northeast</td>
<td>294</td>
<td>182</td>
<td>411</td>
<td>04</td>
</tr>
<tr>
<td>East</td>
<td>89</td>
<td>44</td>
<td>174</td>
<td>14</td>
</tr>
<tr>
<td>Southeast</td>
<td>105</td>
<td>29</td>
<td>149</td>
<td>16</td>
</tr>
<tr>
<td>South</td>
<td>117</td>
<td>23</td>
<td>109</td>
<td>10</td>
</tr>
<tr>
<td>Southwest</td>
<td>101</td>
<td>20</td>
<td>166</td>
<td>09</td>
</tr>
<tr>
<td>West</td>
<td>98</td>
<td>46</td>
<td>151</td>
<td>03</td>
</tr>
<tr>
<td>Northwest</td>
<td>131</td>
<td>372</td>
<td>410</td>
<td>09</td>
</tr>
<tr>
<td>Total</td>
<td>1,338</td>
<td>1,520</td>
<td>2,791</td>
<td>82</td>
</tr>
</tbody>
</table>

Source: Silva et al. (2013)

The coastline and adjacent waters support highly productive marine ecosystems such as fringing coral reefs, shallow beds of coastal and estuarine sea grasses. In early 1960’s, 70,800 ha of low-lying coastal land area has been estimated. Since then, the total area of lagoons and area of coastal wetland have got subjected to various changes due to natural and manmade reasons. The coastal areas are important in supporting the fertility and the productivity of the potential areas for mariculture.

**Blue economy**

The Concept of the blue economy is the conservation and sustainable management of oceans and coastal waters. Blue economy approach recognizes the productivity of healthy ocean ecosystems as a way to safeguard sustainable production from their marine resources, which can offer several benefits to coastal communities in Sri Lanka. The use of coastal areas for mariculture need thorough assessment on environmental, ecological, social and economic consequences on coastal ecosystems, their associated natural resources and the livelihood opportunities of the locality. Detail information on seasonal changes in environmental quality, carrying capacities of the environment, biodiversity, present resource uses, possible impacts due to climate change and strict environmental monitoring plan during operation are essential before allocating these areas for aquaculture activities.
Sustainable mariculture

Mariculture is projected to be the prime source of seafood by 2030, as wild capture fisheries approach their maximum sustainable limits. It can help to provide livelihoods and need of dietary animal protein for global population of nine billion by 2050. An aquaculture industry should develop in harmony with nature and with the confidence of stakeholders for achieving several Sustainable Development Goals (SDGs). Those SDGs include ending hunger, achieving food security, improving nutrition, ending poverty, ensuring healthy life, promoting inclusive and sustainable growth, ensuring sustainable consumption and production and sustainable use of marine resources.

The true sustainable aquaculture system must have non-significant disruption to the ecosystem or cause for the loss of biodiversity or substantial pollution impact. Further, it must be a viable business with long-term prospects with a social responsibility for the community well-being.

Sustainability is a dynamic concept, which varies with species, location, societal norms and the state of knowledge and technology. Several key essential practices have been identified to ensure the sustainability of aquaculture in strategic management planning in EU. Those are categorized under environment, community and business management practices (World Bank, 2014). It describes as below,

Environment practices

The main activities under this are; mangrove and wetland conservation, effective effluent management and water quality control, sediment control and sludge management, soil and water conservation, efficient fishmeal and fish oil use, responsible sourcing of brood stock and juvenile fish, control of escapes and minimizing biodiversity and wildlife impact.

Community practices

Establish well-defined rights, aquaculture zones and responsibilities for aquaculturists, regulatory compliance and effective enforcement, community involvement, worker safety, fair labor practices and equitable compensation are considered.

Sustainable business and farm management practices

Effective biosecurity and disease control systems, minimal antibiotic and pharmaceutical use, microbial sanitation, maintain global standards for hygiene, efficient and humane harvest and transport, accountable record-keeping and traceability, profitability are to be followed.
Guiding principles for the sustainable development of mariculture

Several guiding principles have been identified to provide a broad direction to guide the ongoing sustainable aquaculture in marine environment in some EU countries (National Strategic Plan for Sustainable Aquaculture Development, 2015). Some of those principles in the guideline can be adopted or modified for the mariculture development in Sri Lanka.

**Principle 1 - Responsible planning:** Responsible planning ensures the overall development of aquaculture and responsible management of the marine environment. Such an approach in planning framework, ensures a comprehensive consideration of constraints and synergies and appropriate siting of mariculture sites.

**Principle 2 -** This ensures the maintenance of good water quality and healthy populations of wild species, prevent the escapes, accidental discharges into the environment, avoid harmful interactions with wild fish stocks and, protected habitats and species.

**Principle 3 -** It includes science-based approach in planning, licensing and regulation of the mariculture sector. This will provides the highest level of confidence in the decision-making process and allows for the adoption of a risk and evidence-based approach to determine the monitoring requirements for continuous improvement.

**Principle 4 -** Compliance planning, licensing and regulation of the sector, ensures full compliance with relevant national legislation including Strategic Environmental Assessment (SEA), Initial Environmental Examination (IEE), Environmental Impact Assessment (EIA), wild life protection legislations and other national legislations developed to maintain good environmental status of coastal and marine waters.

**Principle 5 -** Openness, transparency and accountability are core considerations in the licensing and regulatory framework for aquaculture. Seeking public and local knowledge inputs during the process, increases confidence in the decision-making process. Likewise, accountability and openness on the part of the industry will help to educate stakeholders on the social and economic benefits of the industry and ensure an accurate understanding of its potential environmental interactions.

**Principle 6 -** It is desired to develop Better Management Practices (BMP) for mariculture operations, considering best practice for farm operations, health welfare, feed utilization and use of medication for sustainable production. Industry should be supported or encouraged to implement codes of BMP.
Biodiversity and sustainable mariculture development

Sri Lanka is considered as ‘Biodiversity Hotspots’ of the world with a large number of endemic species. Sri Lanka ratified the UN Convention on Biological Diversity (CBD) in 1994. Article 6 of the CBD requires contracting parties to develop a National Biodiversity Strategy and Action Plan (NBSAP). Sri Lanka has developed NBSAP up to 2016 and is now in the process of updating this plan. According to the Aichi targets by 2022, areas under aquaculture are expected to be managed sustainably, ensuring conservation of biodiversity.

Reduction of mangroves and salt marshes, pollution of brackish water and coastal environment, siltation of natural water bodies, introduction of new pathogens to the environment, increase in carrier populations of pathogens, conversion of pyritic sediments for development and extraction of brackish water and ground water in excessive quantities have posed considerable threats to the coastal environment and biodiversity in Sri Lanka.

Formation of sand bars across the sea mouths of estuaries and lagoons is identified as one of the most important phenomena. It affects the coastal processes influencing the biodiversity, fertility and environmental integrity of the areas to be used for mariculture.

Action on the introduction of alien species in mariculture must be considered and quantification of their contribution on environment must be evaluated. There are already objectives and targets related to raise awareness among the aquaculturists to conserve the indigenous variety and eco-system. National Biodiversity Plan (NBSAP) has been developed for taking care of these issues.

Multi-trophic aquaculture and, mixed culture of seaweed and shellfish appear to be a promising approach to reduce environmental impacts, which also improve sustainability of mariculture.

Climate Change and biodiversity are inextricably linked. Climate change may be a driver for loss of biodiversity, conversely biodiversity may support the reduction of negative effects of climate change. Shellfish and seaweed production may contribute to control the carbon emissions through carbon sequestration in shell production and seaweed photosynthesis, which assist in climate change mitigation.
Climate change and sustainable mariculture

Several Climate change impacts on the marine environment such as rising sea temperature, increases frequency of extreme droughts or rains, acidification of ocean etc. pose a number of challenges for the mariculture industry. Sea level rise leading to problems with site suitability and structural damages due to extreme weather are frequently encountered due to climate change. Escapes of farmed fish and their consequences for biodiversity can not be ruled out due to heavy rain. Increase in water temperature, changes the typical growth patterns, affects the timing of spawning and creates disease challenges. Increased frequency/severity of harmful algal blooms may result due to changes in ocean and coastal stratification and increasing temperatures.

Expected changes in climate, extreme weather conditions and climatic events, sea level rise, ocean acidification and rise in temperature are expected to create significant impacts on coastal ecosystems. Adaptation of BMP during site selection, pond construction and preparation, selection of post larvae for stocking, bottom sediment management and disease management may reduce the risk of the impacts due to climate change.

Technical interventions useful in adapting to climate change

This includes avoiding farm sites in environmentally sensitive areas and provides possible interventions to reduce adverse impacts. SEA is a systematic decision support process, aiming to ensure that environmental and sustainability are considered effectively during policy, plan and program making. Environment Impact Assessment (EIA) can look into all possible impacts of climate change and suggest mitigation and adaption measures. Recommendations of EIA will prevent destruction of sensitive eco systems such as mangroves, salt marshes, corals and sea grass beds. Farmers should follow the Environmental Protection License (EPL) to minimize the adverse impacts to be expected during farm operations. It is advisable not to locate farm in the areas under acid sulphate soil. Restoration of mangroves, concept of aquaculture with mangroves, establishment of buffer zones, green belts etc. can improve resilience to raise sea level with additional benefit like reduction of soil erosion pressure on environment. Mangroves have a capacity to absorb pollutants, purify water and enhance the carrying capacity of the environment for sustained farming. Restoration/rehabilitation of mangroves with suitable species can create bio-shields for the protection against cyclone, flood and extreme climatic event. Effective communication and information exchange will
enhance the adaptively for climate change impacts by farmers. Some of the BMP’s are also helpful in mitigation of climate change impacts. Reduction in energy utilization is possible through the use of renewable energy, promotion of low intensity culture, biological treatment of water and integrated multi-trophic aquaculture.

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Chapter 11

Milkfish Aquaculture in Sri Lanka: Progress, Challenges and Opportunities

D.C.T. Dissanayake
Department of Zoology, University of Sri Jayewardenepura
Gangodawila, Nugegoda, Sri Lanka
chamari@sjp.ac.lk

Introduction

Milkfish (Chanos chanos, Forsskal) is one the major species used for brackish water aquaculture in the Indo-Pacific region, mainly in the Philippines, Indonesia and Taiwan over several hundred years (Smith and Chong, 1984). This omnivorous fish is considered as an ideal candidate for aquaculture because of its tolerance to a wide range of salinities (Lee, 1995) and high adaptability to brackish water and freshwater production systems (Lin et al., 2003). Farming of milkfish was exclusively dependent on the wild fry for centuries. Due to inconsistent supply of wild fry and huge fluctuations of their market prices, artificial propagation of milkfish was initiated in the late 1970s (Su et al., 2002). The global annual production of milkfish aquaculture has increased every year since 1997 and the production was 1.18 t, where Philippines, Indonesia and Taiwan province of China are the major contributors during 2016 (FAO, 2016).

Extensive or semi-intensive (50,000 – 100,000 ha⁻¹) systems are widely seen for milkfish culture in the Philippines and Indonesia, where as intensive culture practice with high stocking densities (150,000 to 200,000 ha⁻¹) is seen in Taiwan (FAO, 2007). Rearing of milkfish at a density of 30 000-35 000/ha in freshwater pens with commercial diet was started in Philippines during 1979. Rearing of milkfish in cages is performed in the marine waters where stocking density is maintained from 5 to 30 individuals/m³. Fewer diseases including nematode infestation, anchor worm disease, trichodinosis and cryptobia infestation have been recorded so far in milkfish grow-out farming (Bagarinao, 1998; FAO, 2007). India and Sri Lanka have also taken initiative for milkfish aquaculture (Thayaparan and Chakrabarty, 1984; Jaikumar et al., 2013).
Progress of milkfish culture in Sri Lanka

The first scientific report on culture potential of milkfish in Sri Lanka has been reported by Pillai (1965). He identified natural milkfish breeding grounds at Mannar and Puttlam lagoons. The fry rearing farm at Mannar and an experimental milkfish culture farm at Pitipana were proposed. Experimental culture of milkfish in two 0.12 ha pond yielded 99.9 kg and 144.9 kg after 6 months (Samarakoon, 1970). A pond of 0.7 ha was stocked with milkfish fingerlings at a rate of 2400/ha during 1982. The survival rate was 99%, resulting a production of 547 kg/ha at the end of 5 months culture period (Thayaparan and Chakrabarty, 1984). The experiments on the co-culture of tiger prawn (Penaeus monodon) with milkfish and white prawn (Penaeus indicus) with milkfish revealed that both these culture systems can be carried out successfully in Sri Lanka under the existing environmental conditions (Jayasinhe, 1987; Wanninayake et al., 2001). The milkfish fingerlings collected from wild by the Ministry of Fisheries resulted low yield due to poor pond preparation before stocking during 1980 (Thayaparan and Chakrabarty, 1984). The International Development Research Centre (IDRC) of Canada has successfully carried out the trial of pen culture of milkfish at Puttalam lagoon and Bolgoda Lake during 1980.

National Aquatic Resources Research and Development Agency (NARA) had undertaken a pilot project to map the major milkfish nursery grounds in the Puttalam lagoon in order to facilitate the efficient fry collection during 2001 - 2005. Canadian International Development Agency (CIDA) initiated milkfish farming in brackish water cages at Paalameenmadu area as an alternative livelihood for Tsunami affected fishers during 2007. This programme was not sustained, although high survival (93.33%) and relatively larger size (~500 g) were harvested after the 6 months culture period (Jalaldeen and Periyathamby, 2010). An operation of medium-scale milkfish farming was undertaken using wild collected milkfish fry in Puttalam district during 2005 – 2010, with an aim to provide bait for tuna long line fishery. A pilot study on the hatchery techniques for milkfish breeding was not successful with the technical assistance of Philippine expertise. Although, several attempts were made to initiate milkfish culture in Sri Lanka during different periods, most of these projects did not sustain.

At present three medium-scale (~ 50 acre) milkfish farms are operated in Puttalam district, especially to provide bait for tuna logline fishery. They have successfully carried out the farming activities during the last few years with the wild milkfish fry from the Puttalam lagoon during April to June and October to November. The fry are mainly collected using encircling nets
with 1.5 – 2.0 mm mesh sizes and the fry/fingerlings size vary from 1.0 – 4.0 cm. The ideal time for fry collection is 8.00 – 10.30 AM as they form large schools during this period. The scoop nets and cast nets are also used to collect the fry, accumulated in shallow tidal pools. Farm owners collect the required amount of fry either by themselves or buy from regular fry collectors. Ramanathan (1969) estimated the potential of milkfish fry in the Puttalam lagoon to be around 200 million per year.

Collected fry and fingerlings are transported directly to the farms in plastic buckets or packed in polythene bags. Unwanted species such as *Megalops cyprinoides*, *Elops machnata*, *Oreochromis mossambicus*, *Mugil cephalus* and *Lutjanus spp.* trapped in nets during the milkfish fry collection are removed during the packing or before stocking them into the ponds. The fish farmers pay much attention to remove *Elops machnata* (Mannawa) as they are carnivores. The difficulties are also felt during its early life stages as it is much similar to the milkfish. The presence of one black spot on the head, one on the center of the body and their swimming movement are the main identifying features to separate them from milkfish.

Collected fry are stocked in the brackish water ponds at a density of 50,000 – 80,000/ acre. The stocked fish are fed with prepared feeds two times per day even after the pond preparation for natural algal growth. The culture period is usually 4-5 months and the harvest is mainly marketed in live or in frozen blocks. There is also a good demand for milkfish of 8-9 cm (~80-90 g) as live bait for tuna long line fishery.

**Challenges and opportunities**

Non-availability of adequate wild-caught fry is the main challenge faced by milkfish farmers. Heavy siltation, accumulation of organic debris, habitat destruction and huge salinity fluctuations in the Puttalam lagoon are some possible reasons for decreasing abundance of fry in their traditional nursery grounds. A comprehensive survey to study the abundance and the distribution of milkfish seed and the map suitable for seed collection grounds will provide some solution for this problem. However, the seasonality of seed availability still persists and introduction of the hatchery techniques for artificial proportion of milkfish will be of value to provide concrete solutions to overcome these challenges.

Short-term training programmes for the prospective milkfish farmers on the natural seed collection, scientific handling of seeds and, their transport and stocking procedures would be useful. The current market for milkfish mainly relies on tuna long line fishery apart from its use as food fish. Many
multiday boats are operated for tuna long line in Sri Lanka at present. On the other hand, tuna fishing industry in Sri Lanka is also facing some constrains like quota system on catch, low catch rates, climatic changes, international legal framework and imposition of seasonal bans on the catch, which badly affect the milk fish aquaculture industry. It is also necessary to minimize the unit cost of milkfish production compared to other tuna baits available in the market.

Continuous government support is seen to develop milkfish aquaculture in Sri Lanka as this provides good source of income for coastal fisher folk. Both un-utilized and underutilized fresh and brackish water bodies available in the country can be successfully converted for milkfish farms. Milkfish is an ideal candidate for polyculture systems. Adoption of good technique on artificial propagation, seed rearing and grow-out culture of milkfish will further strengthen the existing opportunities in Sri Lanka.

**References**


Chapter 12

Research and Development in Freshwater Ornamental Fish Sector in Sri Lanka

E.D.M. Epasinghe¹, V. Pahalawaththarachchi² and H.M.P. Kithsiri²

¹Inland Aquatic Resources and Aquaculture Division (IARAD)
²National Aquatic Resources Research and Development Agency (NARA)
Crow Island, Colombo 15, Sri Lanka
vasalanka@gmail.com

Introduction

Ornamental fish industry is a fast-growing sector in the world. Most of the aquarium fish in the global market are sourced from the developing countries of the tropical and sub-tropical regions (Dey, 2016). The ornamental fish industry in Sri Lanka has become a valuable foreign exchange earner (Wijesekara and Yakupitiyage, 2001). Sri Lanka is the 6th largest supplier of ornamental fish to the global market (FAO, 2010).

Ornamental fish industry in Sri Lanka has a long history, with a humble beginning in 1952. Few entrepreneurs about 50 years ago started ornamental fish as a commercial venture and developed into a thriving industry with an export market, affording profit and many employment opportunities (Kuruppu, 1998). Sri Lanka ornamental fish exports consist of marine, freshwater, brackish water fish species and marine invertebrates. Freshwater aquarium fish comprise the more colorful and more striking species of guppies, swordtails, platys, barbs, tetras, angels, gouramis, catfishes etc. Among the exported species guppy (Poecilia reticulata) is the main exporting freshwater fish variety (Haputanthri et al., 2001) which contributes 60-70% (EDB, 2019) of the total exports. The particular species has higher recognition in the international market due to its strength and high diversity than that in the other countries (MFARD, 2015). This potential has encouraged and boosted the sector due to continuous increasing of the world demand.

Ornamental fish industry being a low-cost input operation and high profitability, the sector provides an appropriate form of income and improvement in the living conditions of the farmers. In the year 2015 the total income from ornamental fish sector in Sri Lanka was Rs 1.9 billion (MFARD, 2015).

The major ornamental fish producers in the country are the contract growers. Exporters assist the contract growers by supplying fish fry, feed, chemicals
and basic technology for rearing of aquarium species and ‘buy back’ the fish from the procedures. Ornamental fish breeding, fry raising and grow-out technologies are dealt by the commercial growers whereas marketing is controlled by the ornamental fish exporters. However, the small-scale growers depend on the commercial growers and exporters for technology and marketing. Expansion of this industry among the low-income workforce is an important contributory factor to the economy of Sri Lanka. This is due to its ability to generate considerable income per unit area, with high export earnings, as well as its potential for raising the living standards of the rural communities. It has become a priority of government fisheries policies to uplift the livelihood status of the independent small-scale growers and fish breeders. The success of expansion depends on the availability of appropriate resources, technology, market demands and institutional framework. Therefore, there is an urgent need to develop appropriate strategies for transfer that technology to the ornamental fish breeders by expecting far greater contribution of ornamental fish sector to Sri Lankan economy than at present. It has been planned and carried out a programme on livelihood development of ornamental fish farmers in Colombo, Kalutara and Gampaha districts through breeding high valued ornamental fish species using induced breeding techniques. This project was planned with the objectives of increasing the export volume of exotic high valued egg layer species.

Sri Lankan ornamental fish exporters also have to import the species that are highly competitive in the market chain and re-export them with value addition. Because, such species are still unable to reproduced and develop their progeny under Sri Lankan natural environment conditions. During the last five years NARA developed the induced breeding and propagation protocols for high valued exotic ornamental fish species, Rainbow shark minnow (*Epalzeorhynchos frenatus*), Thailand cat fish (*Pangasius sutchi*) Tin foil barb (*Barbonymus schwanenfeldii*), Indian beauty barb, *Sahyadria denisonii* and Ceylon stone sucker (*Garra ceylonensis*).

Among the ornamental fish production in Sri Lanka, exotic ornamental fishes have a significant demand in the market. Tinfoil Barb (*Barbonymus schwanenfeldii*), which was originated from South-East Asia, is a high demanded exotic ornamental fish in Sri Lanka. *Pangasius sutchi*, commonly known as Thailand catfish, is also a very popular exotic ornamental fish in the country. Before 2012 the industry was dependent on import of this species as captive breeding was difficult. Rainbow shark minnow (*Epalzeorhynchos frenatus*) is commercially important exotic small cyprinid in the worldwide aquarium fish trade. They are native to Thailand in Southeast Asia and also found in Indonesia. The local ornamental fish industry depends on imported
fry from Thailand and Singapore to cater the present demand of the country and no export opportunity creates yet.

Ceylon stone sucker (*Garra ceylonensis*, Bleeker) is a small threatened Cyprinid, endemic to Sri Lanka. It has become the highest exported endemic ornamental fish species from Sri Lanka. They all are collected from wild as there is no initiative of their captive breeding for commercial purposes. Recently, NARA initiated to investigate possibility of developing induced breeding techniques with a view of minimizing the exploitation of wild stocks.

Maintaining water quality is crucial in aquaculture. The ornamental fish are fed on formulated artificial feeds for their nutrient fulfilment. In captive rearing the excess feed and the excreta from fish are accumulated in the water, resulting increase in carbon and nitrogen levels in the culture tanks. Therefore, maintaining the C:N ratio is important to maintain the water quality in culture system. Regular water exchange in the culture systems maintains the water quality in favourable range. In a large scale farming system with a higher number of tanks this is a very costly operation. However, this regular practice has derived several issues such as higher water consumption, higher need of land extents and higher trend of spreading disease. With these arising problems in ground water scarcity and limited land resources, there is a need of a growing system with minimum or zero water exchange within the same culture tanks. “Biofloc technology” (BFT), which is a new approach in aquaculture, can be identified as a solution to these problems. BFT is a technique of enhancing the water quality by addition of extra carbon to the aquaculture system, through an external carbon source or elevated carbon content of the feed (Crab et al., 2012). BFT is used to improve the water quality in aquaculture through balancing carbon and nitrogen in the system. The main principle of BFT is to recycle nutrients by maintaining a high C:N ratio in the water in order to stimulate heterotrophic bacterial growth that converts ammonia into microbial biomass (Avnimelech, 1999; Schneider et al., 2005).

Several studies have shown that the application of biofloc technology plays a role to improve water quality, biosecurity, productivity, feed efficiency and reduce production costs through lowered feed expenses. Theoretically and practically, the application of biofloc technology improves water quality by controlling ammonia concentrations and improving nutrient consumption as it is consumed by the organism cultured (Ekasari, 2009). The findings of (Rachmiwati, 2008) concluded that tilapia fry using zero water exchange system may benefit from waste produced by catfish farms by developing
heterotrophic bacteria. The advantage of biofloc technology is that both waste management to control water quality and production of feed are conducted on site. Few studies have been done to find the impact of BFT on the ornamental fish (Faizullah et al., 2015). NARA has launched first ever studies to fulfill the recognized gaps in ornamental fish aquaculture.

**Livelihood development of ornamental fish breeders**

Livelihood development of ornamental fish breeders was a fully funded project by the Ministry of Fisheries and Aquatic Resources Development and working with the guidance of Inland Aquatic Resources and Aquaculture Division of NARA. Applications were invited from the Sri Lankan citizens in Colombo, Gampha, Kaluthara and Hambanthota district through the mass media in order to select suitable beneficiaries for the project. Twenty-five ornamental fish breeders were selected. A three-days training program on hormonal induced breeding of economically important exotic ornamental fish varieties was conducted. Tinfoil barb (*Barbonymus schwanenfeldii*) was used as the typical fish species for induced practical session. The farmers were trained on brood stock management, induced breeding, identification of fish gender and maturity and operation of Mc Donald jars for maximizing hatching rate of eggs. Operating a Mc Donald type egg hatching jar was introduced first time to the breeders in Sri Lanka. Weighing equipment, inducing agents, structural items for constructing a mini hatchery are the resources that they received at the end of the programme. Matured brooders were supplied in order to quick commencement of fish breeding trials.

Figure 1. Livelihood development program for ornamental fish breeders in 3 districts of Sri Lanka
Thailand cat fish induced breeding protocol

Recent study on spawning success of Pangasius sutchi (Thailand catfish) in Sri Lanka using Ovaprim (Epasinghe et al., 2012)

The study was conducted to determine the techniques of induced spawning of Pangasius sutchi. Brood fish were raised in cement ponds from the beginning (2.5 kg/m³) for 3 ½ years and fed on commercially available diet (CP 35%). Female fish with distended abdomen and pinkish vents were subjected to intra ovarian biopsy. The modal diameters of the oocytes were greater than 1.0 mm (1.12 ± 0.05 mm, on average) and germinal vesicle is being moved to the peripheral (Fig. 3). Males were tested for oozing of milt by applying gentle pressure on the abdomen. Injected two successive doses of Ovaprim (1ml of Ovaprim®, Syndel Laboratories, Canada) contains 20µg of GnRH a and 10mg Dopamine] intramuscularly at 0.3 and 0.7 ml kg⁻¹ of female body weight (BW) at 12 h interval and the male was injected with 0.4 ml kg⁻¹ at the same time as first injection of female. The modal oocyte diameter after 12 h from the first injection (just before second dose of Ovaprim) was 1.31 ± 0.05 mm and observed more rounded and advancement of germinal vesicle migration. The germinal vesicle breaks down (GVBD) (Fig. 4) appeared after 10 h from the second injection. In order to detect the movement of ovulation, gentle stripping trials were performed in every 30 minutes and full ovulation occurred after 12 h latency. Mean water temperature ranged between 27.1 and 28.3˚C during the period of latency. The fertilized eggs hatched within 30-40 h and hatchability was 68%. The injection of 0.5 ml kg⁻¹ of female BW in two doses as ⅓ and ⅔ between 12 h and 10-12 h
latency was successive to get viable eggs, ease stripping response and good hatchability.

Strategies to reduce larval cannibalism of Pangasius sutchi

The effect of feed type and feeding frequency on the cannibalism of Pangasius sutchi (Chathuranga et al., 2013).

The early larval stage of Pangasius sutchi shows cannibalistic behavior which leads to reduction of more than 90% of the population. The experiment was conducted in a completely randomized design (CRD) in two factors factorial arrangement with three replicates to evaluate the effect of feed type (Artemia and Moina) and feeding frequencies (1 hr, 2 hr and 3 hr) on survival and growth of Pangasius sutchi larvae. Tank with 50 larvae considered as an experimental unit and each tank was randomly assigned to one of the treatments. Interaction between feed and frequency was significant (p < 0.05) on survival rate. Cannibalism has been significantly reduced in Artemia fed larvae than the Moina fed larvae. Further, feeding at hourly intervals reduced the cannibalism. The highest mean survival rate was recorded in hourly feeding of Artemia whereas lowest was resulted in feeding Moina in two hours interval. Hence, it can be concluded that feeding Artemia at one hour intervals is the best combination of feed type and the feeding frequency in order to reduce cannibalism of Pangasius sutchi larvae.

Tinfoil Barb induced breeding protocol

Induced breeding of Tinfoil Barb (Barbonymus schwanenfeldii) (Bleeker, 1854) using Ovaprim (Epasinghe et al., 2016)

Tinfoil barb (TFB) of family Cyprinidae is an attractive popular aquarium fish species native to Southeast Asia. There is no authentic record on its natural spawning in captivity condition in Sri Lanka. In 2015 an experiment was conducted to induce the spawning of captive reared TFB using Ovaprim, which contains sGnRHa hormone. At the initial stage, the sexually matured healthy females of 230 g average body weight (BW) were subjected to intra-ovarian biopsy. Later on, the 18 females with migrating germinal vesicles and the males in oozed milt stage were selected for the experiment. Different dosages of Ovaprim viz. 0.2 ml kg⁻¹, 0.3 ml kg⁻¹, 0.4 ml kg⁻¹, 0.5 ml kg⁻¹ and 0.6 ml
kg⁻¹ of BW were injected to the selected females while half a dosage was given to the selected males. All un injected fish were kept as the control. The induced TFBs were kept in 100 l glass tank of preconditioned water at 1:1 male to female sex ratio. In order to determine the ovulation time, after three hours of hormone injection, a gentle pressure was given to each female vent at every half an hour to observe easy expulsion of eggs. The breeding performance of TFBs was determined based on the ovulation time (hrs) and the fertility rate (%). The results indicated that minimum ovulation time (Fig. 6) was 3.20 ± 0.17 hrs at a dosage of 0.6 ml kg⁻¹ of BW. The fertility rate (Fig. 7) with particular dosage was 33.33 ± 9.07%, which was not significant compared to the least fertility rate (27.84 ± 2.36%), obtained with 0.2 ml kg⁻¹ of BW dose.

However, relatively higher fertility rates i.e. 73.33 ± 4.51% and 80.67 ± 5.13 % and minimum ovulation times (5.43 ± 0.51 hrs and 6.10 ± 0.17 hrs) were observed with 0.4 ml kg⁻¹ and 0.5 ml kg⁻¹ of BW dosages, respectively.

In a three months experimental period, TFB was not observed to breed naturally. Therefore, it could conclude that maximum fertility rate and relatively lower ovulation time of TFB can be achieved with 0.4 - 0.5 ml kg⁻¹ of BW Ovaprim for females and half of that for males TFB under captive conditions.
Rainbow shark minnow induced breeding protocol

Induced Breeding of Rainbow Shark minnow *Epalzeorynchos frenatus* (family: Cyprinidae) using Ovaprim (Epasinghe et al., 2013a)

Rainbow shark minnow (*Epalzeorynchos frenatus*) is commercially important exotic small cyprinid in worldwide aquarium trade. They are native to Thailand in Southeast Asia and also found in Indonesia. The local ornamental fish industry depends on imported fry from the Thailand and Singapore to cater to the present demand of the country and no export opportunity creates under this situation. Hence the present study attempts to investigate the possibility of developing an induced breeding technique to support the growing ornamental fish industry. The sub-adults (body weight 8.54 ± 1.3 g and total length 7.05 ± 0.5 cm) were acquired from the local aquarium in November 2012. The fish were reared in cement ponds and provide with 3 % of Body Weight (BW) using commercially available sinking diet twice daily. All fishes were closely monitored weekly for maturity over 12 weeks period. Thereafter, the gravid females were subjected to intra ovarian biopsy once a week. The females with modal diameters of oocytes > 1 mm (1007 ± 50µm, average) and moving germinal vesicle towards the peripheral were subjected to induce breeding trials. The doses of Ovaprim (Ovaprim 1 ml consists of 20 µg of GnRH + 10 mg of Domperidon) 0.25 ml kg⁻¹ of BW, 0.5 ml kg⁻¹ of BW and 0.75 ml kg⁻¹ BW were used as single dose for each female in replicates. At the same time selected males were treated half of the dose used for the females at 1500 hrs. Nine 60 cm x 30 cm x 30 cm glass tanks in indoor system of 20 cm water depth with small stones laid on the bottom (Fig. 9) was used as the spawning tanks. Spawning was observed only the tanks that were treated with the concentration of 0.25 ml kg⁻¹ of BW and 0.5 ml kg⁻¹ BW after 8 hrs. During the latency period temperature range from 27.4 °C – 27.8 °C and pH was measured as 7.3. Their hatching period was 6-10 h and fertility was observed as 8%. Present study revealed the single Ovaprim dose of 0.25 ml kg⁻¹ of BW of female and its half dose for male can
successfully use for breeding of *Epalzeorynchos frenatus* and produce viable eggs with high fertility.

**Ceylon stone sucker induced breeding protocol**

**Initial success of induced breeding of Ceylon stone-sucker Garra ceylonensis (Family: Cyprinidae) using Ovaprim (Epasinghe et al., 2013b)**

Ceylon stone sucker (*Garra ceylonensis*, Bleeker) is a small threatened Cyprinid, endemic to Sri Lanka. It has become the highest exported endemic ornamental fish species in Sri Lanka. They all are wild collected as there is no record of their captive breeding for commercial purposes. Hence, the present study attempted to investigate possibility of developing an induced breeding technique with the view to minimizing the exploitation of wild stocks. The sub adults (body weight 6.87 ± 0.66 g and total length 8.38 ± 0.61 cm) were collected in March 2012 from the Nakkavita stream (Altitude, 90.52 m above Mean Sea Level, latitude 6° 55’ N, 80° 20’ E) in the wet zone. The captured fish were reared in cement ponds and provided with 3% of body weight (BW) of commercially available diet twice a day. All fishes were closely monitored weekly for maturity over 14 week period. Thereafter, the gravid females were subjected to intra ovarian biopsy once a week (Fig. 11). The females with modal diameters of oocytes >1.2 mm (1348 ± 45 µm, average) and moving germinal vesicle towards peripheral were subjected to induced breeding trials. Three doses of Ovaprim (Ovaprim 1ml consists of 20 µg of GnRHα + 10 mg of Domperidon) 0.25 ml kg⁻¹ of BW, 0.5 ml kg⁻¹ of BW...
and 0.75 ml kg\(^{-1}\) of BW were used as single dose for each female in replicates. At the same time selected males were treated with half of the dose (Fig. 12) used for the female at 1500hrs. Nine 60cm x 30cm x 30 cm indoor glass tanks of 20cm water depth with small stones laid at the bottom were used as the spawning tanks. Spawning was observed only the tanks that were treated with the concentration of 0.5 ml kg\(^{-1}\) of BW and 0.75 ml kg\(^{-1}\) of BW after 12hrs. During the latency period, the water temperature ranged from 27.1\(^{\circ}\)C-28.3\(^{\circ}\)C and pH was measured as 8.1. Their hatching period was 36-48h and fertility was observed as 85\%. The study revealed that the single Ovaprim dose ranged from 0.5 – 0.75 ml kg\(^{-1}\) of BW of female and its half dose for male can successfully use for in induce breeding of *G. ceylonensis* and can produce viable eggs with high fertility.

**Biofloc technology in guppy farming**

Guppy fish (*Poecilia reticulata*) is being bred in captivity by a large number of small- and medium-scale producers. Many growers culture guppy fish associated with cement ponds (Haputhanthri et al., 2001) using ground water. The primary goal of aquaculture expansion is to produce more aquaculture products, without significantly increasing the usage of the basic natural resources of land and water (Avnimelech, 2009). However, when expanding grow-out culture systems problems are encountered with obtaining main requirements such as water and suitable lands. Therefore, the study was conducted with an aim of explore the possible contribution of biofloc technology application to guppy aquaculture production, while maintaining sustainable practices. Aquaculture production can be optimized by increasing the production carrying capacity through sufficient supply of good quality guppies, providing an optimum nutrition to ensure maximum growth as well as providing a healthy environment to support the health and welfare of the cultured biota. This study supported to identify possible modifications to improve the ecological performance of a biofloc system and to explore possible beneficial effects of the system on the key factors in the enhancement of guppy production including water quality management and nutritional condition of the cultured animals.

Main objectives of the study were to identification of most suitable locally available carbon sources to assure preferable water quality in the guppy growing system and comparing growth of guppies growing under the different carbon sources in the biofloc system. Three different carbohydrate sources rice bran (RB), wheat flour (WF), molasses and equal mix of rice bran and molasses (MIX) were tested as single (S) and two split (SPL) doses. Acclimatized guppies were divided in to the 24 fiberglass tanks of 120 L
capacity (45 juveniles each one), with air diffuser in the middle line of the tank to assure continuous water movement and suspended particles.

Juveniles were fed twice a day 3% of their body weight (BW) with commercial diet (Prima ornamental fish feed with 40% CP and particle size 1.5 mm – 2.0 mm. Every 15 days, food quantity was adjusted according to their BW for 60 days culture cycle. To assure the biofloc development in the culture system, a C:N ratio of 20:1 (Avnimelech, 2012) was maintained using three locally available carbon sources. A control (Izquierdo, et al.) diet was considered without carbon source. Three replicates were maintained for each treatment. To adjust C:N ratio, carbon requirement calculations was made according to (Emerenciano et al., 2011).

During the period of five weeks study, water in the biofloc tanks were no changed or siphoned except adding evaporated water in to the tanks.

The suitability of the different carbohydrate sources in biofloc system were examined with respect to water quality FCR and SGR of guppies. Results of the study indicated that the total ammonia nitrogen in the tanks was remained below 1.0 mg l\(^{-1}\) for RB, MOL and MIX biofloc systems even without changing water compared to the CON (Fig. 13).

The lowest FCR 1.45 (Fig. 14) resulted for the MIX S and highest SGR (Fig. 15) was recorded at the MIX S and RB SPL, 1.95 and 1.99 respectively. Those values are significantly different (p < .05) with the control.

The results of this study illustrated that the different carbon sources in biofloc

![Figure 13. TAN / mg L\(^{-1}\)](image)

![Figure 14. Mean FCR](image)
system effect water quality and growth performance of guppies in zero water exchange system. In previous studies, it was shown that the biofloc system improves growth performance and FCR (Verma et al., 2016; Zhang et al., 2016). In the current research biofloc treatments recorded a significant lower FCR and improved growth performance than the control.

In conclusion, the study indicated that biofloc system has positive effects on the water quality and on the growth performance of guppies. Among the locally available carbohydrate sources, the best results were observed in rice bran and equal mixture of rice bran and molasses based biofloc.

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References


Chapter 13

Cage Farming of Seabass in Cod Bay, Trincomalee: A Mariculture Venture in Sri Lanka

Irfan Thassim¹, Shabir Ahamed¹, M.B.M. Fayas¹ and M. F. M. Fairoz²
¹Oceanpick Private Limited, 20 Shady Grove Avenue, Colombo 08, Sri Lanka
²Faculty of Fisheries and Ocean Sciences, Ocean University of Sri Lanka, Mahawela Road, Tangalle, Sri Lanka
irfan@oceanpick.com

Introduction

The prevailing trend in global fisheries indicate that the rapid decline of larger predatory fish species landing to alter the marine food web dynamics (Pauly et al., 1998). This was reported and recognized as overfishing (Pauly et al., 2002). Therefore, many of the wild fish stocks are no longer biologically or economically feasible to continue. Development of aquaculture is essential to supply protein diet to the projected human population in the developing world (FAO 2014).

Sri Lanka is a continental Island surrounded by Indian Ocean blessed with locations and conditions are favorable to implement mariculture ventures as a new avenue to food fish production. Sri Lanka’s fishing industry is in needs of a drastic change from its current operations and techniques. The island’s attempts at aquaculture have been primarily concentrated in brackish water lagoons, fresh water bodies or inland based ponds.

This technical paper reports that the first sea cage farming venture presently in operation in Trincomalee, Sri Lanka as Oceanpick (Pvt) Ltd. This venture which ensures controlled production and harvesting of fish aligned with the environmental interests of the modern society.

Objective of this paper to present and overview of the cage farming of Asian Sea Bass/ Baramundi (Lates Calcarifer) in Trincomalee with relation to key operational procedures and environmental monitoring by Oceanpick (Pvt Ltd).

Farming Location

Trincomalee is a natural bay area in the northern part of Sri Lanka which is well known for its clean waters with year around uniform temperatures ideal for Baramundi mariculture. Oceanpick received supports from the
Government of Sri Lanka and its fisheries institutions to uplift the countries fisheries sector profile. Oceanpick with Sri Lanka marine environment specialists conducted extensive research and modelling studies to determine mariculture sites in Trincomalee. The ambient water quality parameters in Cod bay area (salinity: 28 – 33ppt, temperature: 28 – 31 oC, dissolved oxygen: 4.5 – 5.5 ppm) were measured and reported as within favorable range for fish farming.

![Figure 1. Location of Oceanpick Asian Sea bass cage farming site, Cod Bay, Trincomalee, Sri Lanka,](Photo credit – Google Maps)

**Specific characteristics of Barramundi as a viable species for mariculture**

Following specific features were considered to select Barramundi for the cage culture in Cod Bay area, Trincomalee.

- Natural tendency is to shoal and crowd and has wide physiological adaptability
- High fecundity of female fish provides plenty of seeds
- Hatchery production of seed is relatively simple
- Grow well under pelleted diets, and juveniles are easy to wean to pellets
- Rapid growth in short time (6 months – 2 years) to harvestable size (350 g to 3 kg)
Morphometric features of Barramundi

Body elongate, compressed, with a deep caudal peduncle (Fig. 2). Head pointed, with concave dorsal profile becoming convex in front of dorsal fin. Mouth large, slightly oblique, upper jaw reaching to behind eye; teeth villiform, no canines present. Lower edge of pre-operculum with a strong spine; operculum with a small spine and with a serrated flap above origin of lateral line. Lower first gill arch with 16 to 17 gill rakers. Scales large, ctenoid. Dorsal fin with 7 to 9 spines and 10 to 11 soft rays; a very deep notch almost dividing spiny from soft part of fin; pectoral fin short and rounded, several short, strong serrations above its base; dorsal and anal fins both have scaly sheaths. Anal fin rounded, with 3 spines and 7 to 8 short rays. Caudal fin rounded. Colour in two phases, either olive brown above with silver sides and belly (usually juveniles) or green/blue above and silver below. No spots or bars present on fins or body (FAO, 2006).

Sexual maturity

Barramundi mature sexually at two to three years of age. The fish mature initially as males and participate in one or more spawning seasons before undergoing a sexual inversion (protandry), becoming functional females by the next breeding season.

Commonly fish less than 80 cm in length are males and those greater than 100 cm are females. This is not always the case as sexually precocious (fish that mature and change sex at a smaller than usual size). Captive barramundi has often exhibited a very short male phase becoming functional females when they reach 50–60 cm n length. The reasons for this have been variously attributed to the captive environment, increased and
more regular feeding or hormone treatments used during the spawning season (FAO, 2006).

**Spawning grounds**

Barramundi can live in either fresh or salt water, their eggs (large female Barramundi can produce 32 million eggs in a season) and early stage larvae will only survive in sea water (salinities between 22 and 40 ppt). For this reason, breeding takes place in river mouths and bays near areas of suitable nursery habitat. Areas such as mangrove swamps and low-lying land that becomes flooded during spring tides and monsoonal rains provide deal habitat for juvenile barramundi (FAO, 2006).

**Nutritional facts**

Barramundi can grow to a size of 1.5 kg to 2 kg in less than two years. It is a highly suitable species for ocean fish farming. It contains only 137 calorie with only 2.5g of ‘good fat’ per portion, which is half the calories of salmon, and tops the healthy food choices list. No saturated fat is contained in Barramundi’s fillet, although it does have 70 mg of cholesterol, which is 23% of the total a healthy adult should have each day. A serving of some commercially farmed barramundi contains about 1 g of omega-3 fatty acids, nearly as much as the 1.5 g of omega-3 fatty acids found in every serving of fatty fish like salmon, mackerel or herring. A diet high in omega-3 fatty acids may help lower your cholesterol and decrease your risk of heart disease, cancer and neurological disorders. The Centers for Disease Control and Prevention says that the average adult woman needs 46 g of protein per day, while a man should have about 56 g. Barramundi supplies 35 g of protein in a 6-ounce fillet - that's 76% of a woman's protein RDA and 62% of a man's daily protein requirement. You may have a better chance of avoiding chronic diseases such as diabetes, cancer and heart disease if you get more of your protein from plant-based sources, poultry or seafood, rather than red or processed meats. Barramundi was a source of a number of essential vitamins and minerals that support your immune, cardiovascular and nervous systems, including selenium, zinc, magnesium, vitamin A and calcium. Each 6 ounce fillet of barramundi contains 40 mg of calcium or 4% of the 1,000 mg daily recommended intake for adults. Barramundi also provides approximately 4% of an adult's required intake of vitamin A.
Production technology of Barramundi

Hatchery production technology

Hatchery production begins with the spawning of broodstock (captive breed fish) and is completed when the small fish or ‘fingerlings’ are about 25 mm long.

Nursery production technology

The Barramundi that is acquired from the hatchery at the size of around 25 mm goes into the nursery stage. It encompasses the completion of the process of weaning the fish from a live food diet onto formulated feeds. Currently Oceanpicks nursery is in full operation where sea water is pumped to the round tanks (Fig. 3). The Juveniles spend about 2 months until it reaches about 30-40g in weight, before transfer to the sea cages (grow-out).

Figure 3. Structure of nursery system of Oceanpick Seabass cage farming site, Trincomalee, Sri Lanka

Water is taken for nursery from well of shore of ocean through submergible pumps. Then water is sent through the bio-filter and stock tank is filled by that water. It is sent through the sand filter (Fig. 3) and finally inlet water is released to fish tank. Outlet water of fish tank is sent to treatment tank and then released to the open ocean.
Sea cages

The transferred fingerlings are stocked in the sea cages which are located in the deeper waters of Trincomalee, Sri Lanka. Oceanpick adapts Scottish standards which opens up a great opportunity for the local people to gain the knowledge of modern marine aquaculture practices for the first time in South Asia. The grow out cages are directly placed in the sea which are made out of black polyethylene, PVC and steel (Fig. 5). The farm at Trincomalee harbor in north-east Sri Lanka comprises of four 40m circumference Marine pens with safety workstations.
Production Cycle

Figure 6. Schematic representation of production cycle of Oceanpick Asian Sea bass cage farming, Trincomalee, Sri Lanka.

Barramundi life cycle has primarily 3 stages, namely hatchery stage, nursery Stage and grow-out stage. In a year time the post larvae reach 500g and within 2 years the fish can grow up to 3kg (Rimmer, 2003).

Hatchery/Nursery Maintenance

Figure 7. Submergible Pump used in farming site, Trincomalee, Sri Lanka.
(Photo credit – Oceanpick)
Submersible pump is a device which has a hermetically sealed motor close coupled to the pump body (Fig. 7). The whole assembly is submerged into well of the near shore of ocean. Submersible water pump pushes water to the surface, instead of sucking the water out of the ground like ground water pumps. This pumps basically used principle of centrifugal pumps operating in a vertical position.

**Advantages of obtaining deep well water**

- Very clean water
- Minimum of pollutants compare with ocean surface water
- Dissolved oxygen rate was very low which reduce the activity of any aerobic microorganisms
- Water can obtain in same condition around the year

Pipes and sockets are used to connect the system from pump. Best quality pipes and sockets were used because of high pressure. Water is sent trough the bio-filter before sent to the stock tank (Fig. 8) to remove the Ammonia and nitrite. Pumped sea water is stored into stock tank. The capacity of that tank is 190500 L. And also, it is used as a sedimentation tank, which allows all suspended materials to settle to the bottom.

![Figure 8. Water storage tank at farming site, Trincomalee, Sri Lanka.](Photo credit – Oceanpick)
Sand filtration units (Fig. 9) are required when the quality of the seawater brought to the facility has high levels of suspended solids. It enhances the quality of the seawater and reduces the level of fouling and disease organisms.

![Sand Filters](image1.png)

Figure 9. Sand filters installed at farming site, Trincomalee, Sri Lanka. (Photo credit–Oceanpick)

The nursery has a reticulated pure oxygen system (Fig. 10). The pressured oxygen cylinders are installed with a oxygen line system and the line is plumbed directly to water line for supply. Then the aerated water is supplied to fish tanks and emergency oxygen is also provided to the fish tank by aerators. Fish tanks are made by fiber (Fig. 11), Cone shaped and outlet pipe is placed at the center of the tank. Water is managed at tanks to the same level by controlling the exchange. Accumulation of fecal matters and other particles are prevented by continuous water circulation in all tanks. That helps to improve the quality of water.

![Oxygen Cylinders](image2.png)

Figure 10. Oxygen cylinders installed at farming site, Trincomalee, Sri Lanka. (Photo credit – Oceanpick)

![Fish Tank System](image3.png)

Figure 11. Fish tank system at farming site, Trincomalee, Sri Lanka (Photo credit – Oceanpick)

Good care is taken prior to release used water to open ocean. This step involves with a Treatment tank (Fig. 12).
Waste water treatment steps

- Sedimentation: Outlet waste water is sent to sedimentation partition where allowed to particle sedimentation. Then sediment free water is sent to chlorination partition
- Chlorination: Water is disinfected by chlorine
- Aeration: Water is aerated by aerators
- Released to open ocean

These are some of the Bio security measures to prevent disease infection in the farm

- Deep well water is used for fish rearing
- Foot bath placed at entrance of nursery
- Prevention of animal and bird entries
- No entry to unknown people
- No entry to ill people
- Disinfecting agents are used
- Total nursery system is cleaned after every production cycle

**Feeding of Barramundi in Cages**

The fish diet used at farm site contains 45% protein that goes directly into the fish assuming 100% efficient because unlike wild fish that has to use ample amount of energy to find the balance diet, farmed fish use very low energy to get their diet because it’s fed directly into their cages. Feeding is generally done twice per day for the smaller fish and once per day for the larger fish with different palette sizes depending on their sizes. Satiated feeding is important; not only does it keep the fish satisfied but it eliminates competitions from the cage. If under fed, aggressive fish will get the food first, overtime they will become a large enough size to become cannibalistic. Cannibalism is an inherent characteristic of Barramundi and this also present in most other farmed species. The cages are stocked with evenly sized fish to mitigate cannibalism.

**Post-harvesting techniques to assure quality products and marketing**

**Cold chain management**

It’s important to minimize the damage and stress of the harvested fish, Oceanpick uses modern technologies during harvesting and follows hygienic post-harvest practices. The cold chain process starts immediately
after harvesting where the fish are gutted and placed straight in ice without delays.

Everyone who handles chilled fish down the food chain has a prime responsibility to treat it with utmost care. It may only be a 'dead fish' to handler, but it is 'food' to someone else. Thus, everyone involved in PHM (Post-harvest Management) has responsibility of preservation of freshness and deliver a clean and hygienic product, which can be bought, transported and prepared conveniently.

Retardation of bacterial and autolytic spoilage

Bacterial and autolytic spoilage occur most at certain temperatures. Temperature control offers the most common and practical way of keeping fish fresh. There are two methods of lowering temperature in practice: chilling and freezing. Chilling requires the fish to be held at a temperature as close to 0°C (± 2). Chilling can increase the storage life of fish up to 14 days. As chilling is a short-term storage method, Oceanpick maintains an on-demand harvesting process where harvesting is carried out based on the demand predicted.

Conclusion

Quality of maricultured Barrramundi

Oceanpicks Barrramundi has better fish quality due to the oceanic conditions they are raised in. Also, offshore farming ensures that uses of antibiotics are greatly reduced because the natural marine environment. Annual Barrramundi sales report shows increasing of sales from 2016 – 2018. Product is supplied to local and internal markets.

Employment opportunities to local community

Abundant pool of coastal work force is already skilled in fishery in Northern coastline, but lagging economically behind due to lower fish catches from wild stocks. Oceanpick cage Barrramundi farm in Cod bay area provided opportunity to employ from the local fisher community (Table 1). The project has generated direct and indirect job opportunities for over 75 local residents. The company also helps the local businesses such as hardware stores, ice producers, transporters and other suppliers with constant material purchases which enhances other local businesses in the area.
Table 1. Employment records of Oceanpick Barramundi farm in 2018

<table>
<thead>
<tr>
<th>Job</th>
<th>Employment</th>
<th>Beneficiaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>65</td>
<td>Permanent employment in the region (Fisherman and their families)</td>
</tr>
<tr>
<td>Indirect</td>
<td>40</td>
<td>Local fisherman, distributors, logistics companies, tourism, farmers</td>
</tr>
</tbody>
</table>

**Skill development in mariculture**

Locals are taught a new skill through the farm operation that never existed in Sri Lanka. University graduates expecting specialization in Aquaculture or Fisheries received training to enhance knowledge and on hand experience in offshore fish culture in cage practiced to Scottish standards. This experience can only be received from Oceanpick as a pioneer in mariculture venture in Sri Lanka.

**Future opportunities**

Oceanpick has plans to create more facilities in the region such as fish processing facilities in Trincomalee which will further increase employment in the area. In the future aim to help the local fisherman in to business by linking them to our customers as a help to the local community to enter in to a global market that they never had access to.

**References**


Opening of the consultation

The SAARC Agriculture Centre (SAC), Dhaka, Bangladesh and the National Aquaculture Development Authority of Sri Lanka (NAQDA), Ministry of Agriculture, Rural Economic Affairs, Livestock Development, Irrigation and Fisheries & Aquatic Resources Development, Sri Lanka jointly organized the SAARC Regional Expert Consultation on ‘Development of Aquaculture for Commercially Important Finfishes in South Asia’ at Hilton, Colombo during 26-28 March 2019. Dr. Shiba Shankar Giri, Senior Program Specialist (Fisheries) was the Program Coordinator and led the SAARC delegation of Colombo. Dr. (Mrs.) J. M. Ashoka, Director (Coastal Aquaculture Development), NAQDA, Sri Lanka was the local coordinator of the regional consultation meeting. The meeting was attended by the National Focal Point experts of six SAARC member countries, experts from Sri Lankan Agricultural Research Council, SAARC Agriculture Centre, Ministry of Agriculture, Rural Economic Affairs, Livestock Development, Irrigation and Fisheries & Aquatic Resources Development, Sri Lanka, NARS of Sri Lanka and the public and private entrepreneurs in Sri Lanka. The welcome addresses were delivered by Hon’ble Dilip Wedaarachchi, State Minister of Fisheries and Aquatic Resources Development, Government of Sri Lanka, Mr. K.D.S. Ruwanchandra, Secretary, Ministry of Agriculture, Rural Economic Affairs, Livestock Development, Irrigation and Fisheries & Aquatic Resources Development, and Mr. N.P. Madawan Arachchi, Chairman, NAQDA, and Dr. S.S. Giri, Senior Program Specialist (Fisheries), SAARC Agriculture Centre, Dhaka, Bangladesh.

Objectives

- Identification/listing of the commercially important cultivable finishes of South Asia that are of high market demand and export potential
• Review the research and development needs for sustainable finfish aquaculture development in the SAARC countries
• Coordination of the regional research, extension and training activities to assist the development of sustainable finfish culture in South Asia

Papers presented
A total of six country papers on ‘Development of Aquaculture for Commercially Important Finishes in South Asia’ were presented in the expert consultation, covering Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. Another six technical papers covering crucial aspects of commercially important finfish aquaculture and their opportunities, challenges, available policies and future needs were also presented by the acknowledged experts from the SAARC member states in these special fields.

Recommendations

Policy issues
• Spatial planning and zoning to keep aquaculture within the surrounding ecosystem’s carrying capacity and to lessen conflicts over resource uses
• Development and promotion of cooperative system to facilitate inputs and to lift the products from the finfish aquaculture site
• Introduction of aquaculture insurance program that provides coverage for losses and damages
• Networking and collaboration for capacity building between research and development institutions among regional, international and donor country research centres
• Policy guidelines involving the participation of the private sector in aquaculture researches in all aspects from production to trade
• Establish procedures to undertake appropriate environmental impact assessment and monitoring to minimize adverse ecological changes due to aquaculture

Trade issues
• Development of SAARC regional BMP, standards for fish and fish products, farm-based Hazard Analysis and Critical Control Points (HACCP) food safety systems and mechanisms to enable product traceability
• Processing and value addition of aquaculture products for export as well as local market
• Maintain and promote security of access to international trade, and proactive measures to avoid tariff and non-tariff trade restrictions
Social issue
- Empowering communities and strengthening community participation in aquaculture and its management
- Introducing incentives to reward sustainability through access to training, water supply, wastewater treatment, low-interest loans and tax exemptions to small and marginal farmers

Environmental issues
- Regulatory to protect biodiversity in SAARC regional water bodies from irresponsible aquaculture practices
- Leverage the latest information communication technology (ICT) in aquaculture
- Vulnerable species may be identified and prioritized for conservation
- Expansion of the farming of fish species of lower trophic level, least water exchange systems, use of SPF and SPR strains and other management options to adapt to climate change impacts
- Moving towards reduction of carbon footprint in aquaculture
- Zone-wise commercially valuable stress tolerant species may be identified and cultured for better adaptation to climate change impacts
- Integration of aquaculture, livestock, agriculture and other production systems or ecosystem management activities
- Promote locally available resources in aquaculture to reduce production cost

Following this Expert Consultation, which has recorded for the first time, the importance of developing commercially important finfish aquaculture in South Asia, their opportunities, challenges and necessary policy interventions needed for sustainable aquaculture development in the SAARC region should

- recognize that the consultation has only made a first step in gathering information on the topic;
- collect and collate information on emerging issues and challenges in finfish aquaculture and its commercial importance, institutional frame work and capacity available in SAARC member countries; and
- organize further meetings and finally drafting the policy to be followed for aquaculture development of commercially important finfishes in south Asian region. Also, framing policy for technological and financial support to farmers of the region for development of aquaculture of diversified finfishes as livelihood support and revenue earning through export and trade.
LIST OF PARTICIPANTS

BANGLADESH
Mr. Kazi Iqbal Azam
Deputy Director
Department of Fisheries
Dhaka, Bangladesh
Email: kaziqbalazam@yahoo.com

BHUTAN
Mr. Drukpola
Sr' Veterinary Officer
Research and Development Center for Aquaculture
Department of Livestock
Ministry of Agriculture and Forests
Gelephu, Sarpang
Bhutan
Email: drukfishcos@gmail.com

INDIA
Dr. Pratap Chandra Das
Principal Scientist
Central Institute of Freshwater Aquaculture
Kausalyaganga, Bhubaneswar, India
Email: pratapcdas@yahoo.com

NEPAL
Mr. Subhash Kumar Jha
Fisheries Development Officer
Central Fisheries Promotion and Conservation Centre
Kathmandu, Nepal
Email: jhasubas2012@gmail.com

PAKISTAN
Mr. Fahad Saleem
Assistant Director (SAARC)
Islamabad, Pakistan
Email: fahad.saleem@mofa.gov.pk
SRI LANKA

Dr. (Mrs.) J. M. Asoka
Director
Coastal Aquaculture Development
National Aquaculture Development Authority of Sri Lanka
Colombo, Sri Lanka
Email: asokajm@yahoo.com

NARS, SRI LANKA

Mr. N. P. Madawan Arachchi
Chairman
National Aquaculture Development Authority of Sri Lanka
Colombo, Sri Lanka
Email: chairman.naqda@gmail.com

Mr. P. Nimal Chandratne
Director General
National Aquaculture Development Authority of Sri Lanka
Colombo, Sri Lanka
Email: dg.naqda@gmail.com

Prof. U.S. Amarasinghe
Senior Professor
Department of Zoology and Environmental Management,
University of Kelaniya, Sri Lanka
Email: zoousa@kln.ac.lk, upali54@gmail.com

Prof. J.M.P.K. Jayasinghe
Senior Professor
Wayamba University, Sri Lanka
Email: jmpkjaya@gmail.com

Dr. (Mrs). Chamari Dissanayake
Senior Lecturer
Department of Zoology, University of Sri Jayewardenepura
Gangodawila, Nugegoda, Sri Lanka
Email: chamid4@gmail.com, chamari@sjp.ac.lk

Mr. H.M.U.K.P.B. Herath
Director (Freshwater Aquaculture Development)
National Aquaculture Development Authority of Sri Lanka
Colombo, Sri Lanka
Email: herathup@yahoo.com

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Mr. A.R Mudalige  
Fish Genetic Specialist  
National Aquaculture Development Authority of Sri Lanka  
Colombo, Sri Lanka  
Email: ajanthamudalige@gmail.com

Mr. P.M. Withanage  
Fish Nutrition  
National Aquaculture Development Authority of Sri Lanka  
Colombo, Sri Lanka  
Email: prabathnaqda@gmail.com

Mr. W.P.R. Chandrarathne  
Fish Pathologist  
National Aquaculture Development Authority of Sri Lanka  
Colombo, Sri Lanka  
Email: palitha.chandrarathna@gmail.com

Mr. W. C. Jayaweera  
Assistance Director (Investment Promotion)  
National Aquaculture Development Authority of Sri Lanka  
Colombo, Sri Lanka  
Email: chamila62@gmail.com

Mr. S.H.A. Sirirkumara  
Assistance Director (Freshwater Aquaculture Development)  
National Aquaculture Development Authority of Sri Lanka  
Colombo, Sri Lanka  
Email: ajithkumara16@yahoo.com

Mr. R.M. Keerthisiri  
Assistance Director (Freshwater Aquaculture Development),  
National Aquaculture Development Authority of Sri Lanka  
Colombo, Sri Lanka  
Email: oic.inginiyagala@naqda.gov.lk

Mr. C.K. Sapumohotti  
Assistance Director (Zone 04)  
National Aquaculture Development Authority of Sri Lanka  
Colombo, Sri Lanka  
Email: oic.inginiyagala@naqda.gov.lk

Dr. (Mrs.) Wasantha Pahalawattaarachchi  
Head / Inland Aquatic Resources and Aquaculture Division  
National Aquatic Resources Research and Development Agency (NARA)  
Crow Island, Colombo 15, Sri Lanka  
Email: vasalanka@gmail.com
Dr. M.G.I.S. Parakrama  
Senior Scientist  
National Aquatic Resources Research and Development Agency (NARA)  
Crow Island, Colombo 15, Sri Lanka  
Email: parakrama@nara.ac.lk

Mr. P.A.D. Kumara  
Senior Scientist  
National Aquatic Resources Research and Development Agency (NARA), Crow Island, Colombo 15, Sri Lanka  
Email: padajithkumara@yahoo.com

Mr. E.D.M. Epasinghe  
Scientist  
National Aquatic Resources Research and Development Agency (NARA), Crow Island, Colombo 15, Sri Lanka  
Email: edmepasinghe@gmail.com

Mrs. K.A.C.P. Kodithuwakku  
Assistance Director  
Department of Fisheries & Aquatic Resources  
New Secretariat  
Maligawatta  
Colombo 10, Sri Lanka  
Email: chathurikakacp@yahoo.com

Dr. M.F.M. Fairoz  
Senior Lecturer  
Faculty of Fisheries and Ocean Sciences, Ocean University of Sri Lanka, Mahawella Road, Tangalle, Sri Lanka  
Email: fairoz.mfm@gmail.com

Mr. Irfan Thassim  
Oceanpick Private Limited  
20, Shady Grove Avenue, Colombo 08, Sri Lanka  
Email: irfan@oceanpick.com

SAARC AGRICULTURE CENTRE, DHAKA

Dr. Shiba Shankar Giri  
Senior Program Specialist (Fisheries)  
SAARC Agriculture Centre, BARC Complex, Farm gate  
Dhaka-1215, Bangladesh  
E-mail: ssgiri1965@gmail.com